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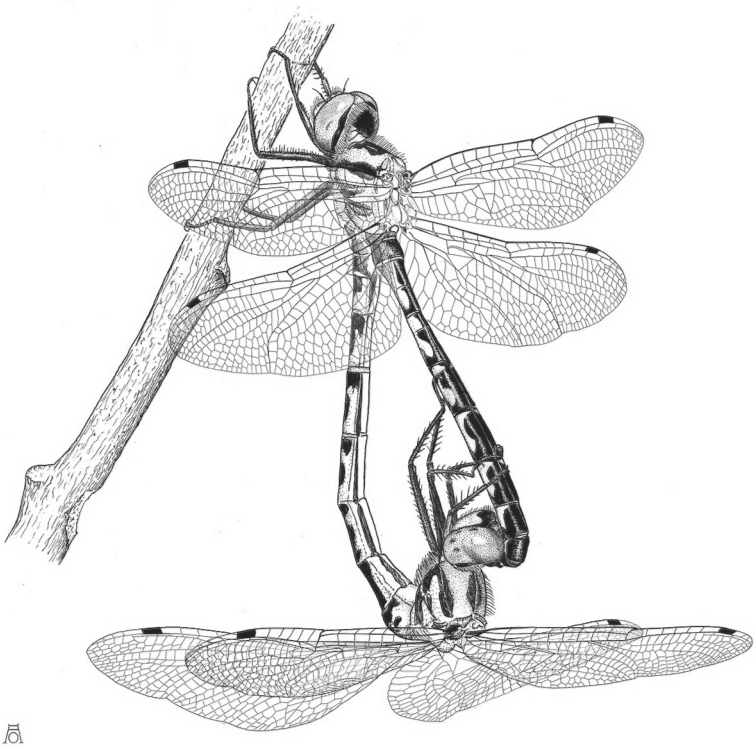

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THE EXOTIC WHITEGRUB *PLECTRIS ALIENA* CHAPIN (COLEOPTERA: SCARABAEIDAE: MELOLONTHINAE) IS MORE WIDELY DISTRIBUTED IN AUSTRALIA THAN PREVIOUSLY THOUGHT

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Abstract

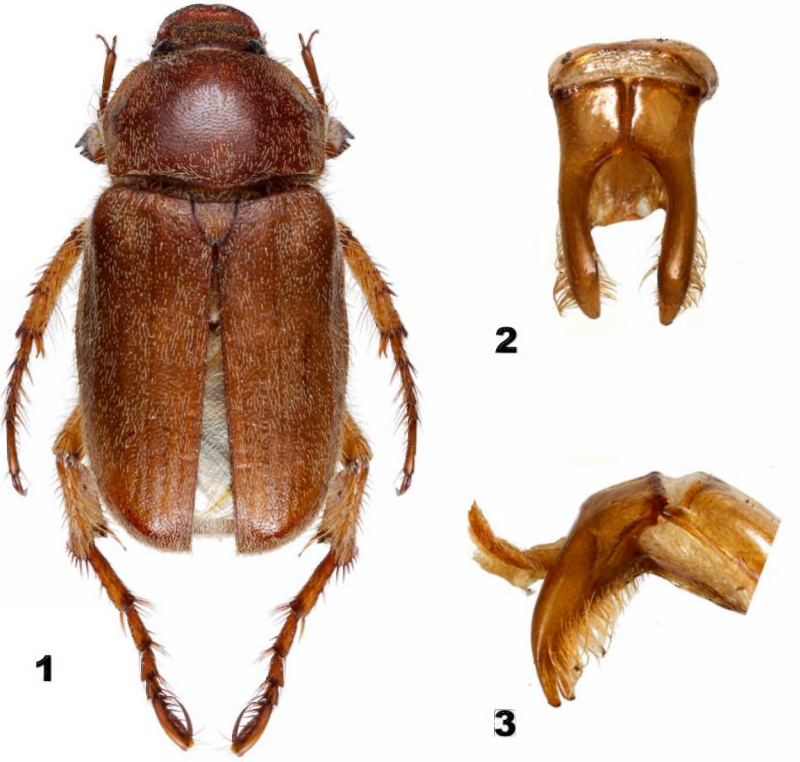
Specimens of the South American *Plectris aliena* Chapin collected in and north of the Sydney area and in the Hunter Valley in New South Wales, provide a significant extension of the known Australian range of this species from Casino in northeastern New South Wales. Previously, it was speculated that this species might have been introduced through the port of Newcastle but this extension suggests that Sydney might be more likely. Movement to the Casino and perhaps the Hunter Valley areas was likely to have been human assisted.

Introduction

Within the phytophagous scarabs three exotic dynastines are known to have established in Australia – the South American *Cyclocephala signaticollis* Burmeister, 1847 (Carne 1956, 1957), plus the African *Heteronychus arator* (Fabricius, 1775) (Gurney 1934, Carne 1957) and *Temnorrhynchus retusus* (Fabricius, 1781) (Allsopp 1987, Krell and Hangay 1998). In addition, Carne (1981) reported females of an unidentified dynastine, presumably of exotic origin, collected in southeastern New South Wales. *Cyclocephala signaticollis* has spread north from the Sydney area to beyond Brisbane (Monteith 2017) and south to Canberra (Jackson and Klein 2006), while *H. arator*, also known from Western Australia and South Australia, has spread north from Sydney to at least Maryborough in Queensland (Allsopp *et al.* 1993). *Temnorrhynchus retusus* is known from around Albany in Western Australia and the Sydney region and Bateman's Bay in New South Wales. In addition, there are old records of the dynastines *Oryctes rhinoceros* (Linnaeus, 1758), *Heteronychus parumpunctatus* Burmeister, 1847 and *Pentodon bispinosus* (Herbst, 1789), plus various *Anomala* spp (Rutelinae), all introductions which do not appear to have persisted (Carne 1957, 1958). All these species have relatively long-lived adults that could have survived a sea voyage, although larvae or a mixture of larvae and adults could have arrived in potted plants, in soil used as ship's ballast, or as stowaways in cargo in ships or airplanes.

Plectris aliena Chapin, 1934 (Macrodactylini) was reported from Australia by Roberts (1968). This species (Figs 1-3) was described from South Carolina (Chapin 1934) and is now known from the southeastern States (Brill and Abney 2014) but it is not endemic to North America. Roberts (1968) argued that it had come to Australia from the Río de la Plata area of Argentina-Uruguay, but Frey (1967) and Evans and Smith (2009) recorded it

(without further comment) only from 'Paraguay', further up the Río Paraná/Río Paraguay that flow into the Río de la Plata. Adults are short-lived and do not feed, so would not have survived a voyage to Australia from either South America or the southeastern USA. Larvae in soil used as ship's ballast was the obvious introduction mechanism (Roberts 1968), although potted plants could have transferred larvae.



Figs 1-3. *Plectris aliena*: (1) male; (2) aedeagus, dorsal view; (3) aedeagus, lateral view (from Guy A. Hanley and used with permission).

Roberts (1968) knew *P. aliena* only from the Casino area of northeastern New South Wales, where larvae were damaging pastures in areas of deep, sandy soil where seasonal drainage is impeded; it also occurs on similar soils in the USA (Chapin 1934, Brill *et al.* 2013). Samson *et al.* (2013) listed it as damaging sugarcane in the same area as did Roberts, while Brill and Abney (2013) listed a wide range of plants damaged by larvae. Roberts could not imagine that it was introduced directly to the Casino area from either South America or the USA and speculated that it had come in through Newcastle,

470 km south of Casino, during the late 1800s/early 1900s coal trade from that area to South America, being moved subsequently to the Casino area. Roberts briefly surveyed from Newcastle to Ballina (on the coast east of Casino) but did not find it. We know of no further published records of this species in Australia, apart from the catalogue entry by Houston and Weir (1992).

Britton's (1957) key to tribes of Australian melolonthines did not include the Macrodactylini but his revised key (Britton 1978) did, albeit without comment. The combination of each posterior tibia with two spurs placed below the tarsal articulation so that the tarsus can pass only above the spurs, pretarsal claws unequal on the hind legs, male with spurs on the posterior tibiae reduced to mere stubs, the claws on all legs bifid and moveable in one plane with fifth tarsal segment ventrally cleft to allow movement of one or both claws, and a yellowish brown dorsum with dense, short setae (Fig. 1), together with the slightly asymmetrical shape of the aedeagus and its dense setae (Figs 2-3), easily separate *P. aliena* from the endemic Australian melolonthines. In males, the antennal club is about 1.5 mm long, whereas in females it is about 0.8 mm long.

Our interest in this species was sparked when we identified as *P. aliena* specimens from Woy Woy (about 75 km south of Newcastle), collected by F.T. Fricke and in PMH's collection. A search of material in the Australian Museum, Australian National Insect Collection and NSW Department of Primary Industries collection found further specimens from Woy Woy and nearby Ourimbah, as well as from localities in the Sydney Basin, the Hunter River region and west of Casino (Fig. 4). Most collection data are from November and December, with a few labelled February, March, May, June or August that might refer to larvae collected and reared. There is no material in the Queensland Museum, University of Queensland Insect Collection or Queensland Department of Agriculture and Fisheries collection, indicating no significant spread north of Casino.

These records indicate a much wider established distribution than recorded by Roberts (1968). Emergence, flight and mating occurs for only 15-20 minutes after sunset and females do not appear to disperse widely, burrowing into the soil immediately after mating (Roberts 1968). This suggests that natural dispersal would be slow and that significant movement (such as to Casino and perhaps to the Hunter Valley) could only be through human-assisted transportation. The occurrence of *P. aliena* across the Sydney region also casts doubt on Roberts' hypothesis of Newcastle as its entry point – it is more likely to have been Sydney. It is tempting to speculate that *P. aliena* might have arrived in potted plants with returning settlers from the failed Colonia Nueva Australia (25°25'S, 56°35'W) experiment in Paraguay in the late 1890s (Whitehead 1997), but there are no specimens in collections from earlier than 1963 (Casino, Hunter Valley and Sydney areas).

This identification also sparked our interest in Fred Fricke and his collection. Fricke was an amateur collector who, in later life, became quite eccentric and was living in a ramshackle terrace house at Bondi Junction in Sydney. After he died and his house was cleared of weapons and explosives, his collection was sold to Mark Hanlon (Barker 2001); most of the scarabs passed to PMH in early 2017.

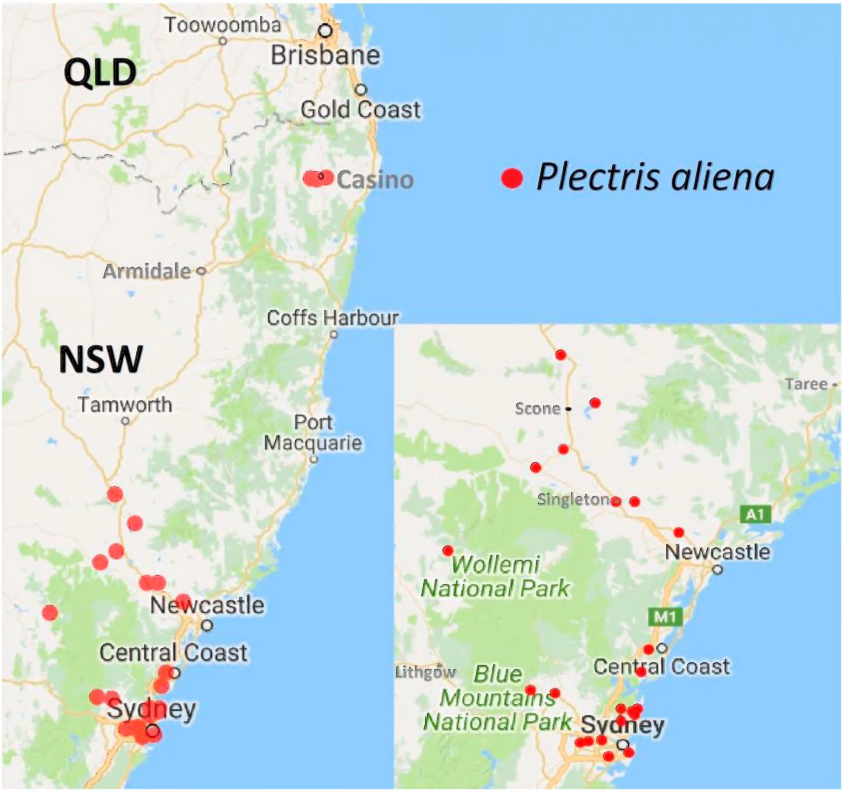


Fig. 4. Known distribution of *Plectris aliena* in New South Wales.

Acknowledgements

We thank Derek Smith, Chris Reid, Tom Weir and Ainsley Seago for information from collections in their care, Geoff Monteith for help with the map and Guy Hanley for use of his photographs. Two referees are thanked for providing useful comments.

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THE FIRST RECORD OF *EUPYRGOTA* COQUILLETT (DIPTERA: PYRGOTIDAE) FROM AUSTRALIA

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Abstract

Eupyrgota Coquillett is newly reported from Australia, based on a female specimen of the widespread species *E.* (*Taeniomastix) pictiventris* (Hendel, 1914) collected in Cairns in northern Queensland and an undescribed species from the Iron Range area of Cape York Peninsula, NE Queensland.

Introduction

The pyrgotid genus *Eupyrgota* Coquillett is known predominantly from the Afrotropical, Palaearctic and Oriental Regions, with a few species reported from the Papuan Subregion of the Australasian Region, including *E. aequalis* (Malloch, 1939) from Papua New Guinea (Korneyev 2014a, b). *Eupyrgota* has not been reported previously from Australia (Paramanov 1958, Pitkin 1989) but confirmation of its presence is provided by a specimen attributable to the widespread species *E.* (*Taeniomastix*) *pictiventris* (Hendel, 1914), collected in Cairns in northern Queensland. In addition, both sexes of an undescribed species are known from the Iron Range area of Cape York Peninsula, northeastern Qld [specimens in Queensland Museum, Brisbane], distinguished by its dark body colour and small size (wing length 8 mm). Adult pyrgotids are generally scarce in collections and fly at dusk; where known, their larvae are endoparasitic in the abdomens of adult scarabaeoid beetles (Melolonthinae, Rutelinae and Cetoniinae: Korneyev 2014a).

Eupyrgota Coquillett

Eupyrgota Coquillett, 1898: 337. Type species *E. luteola* Coquillett, 1898.

This genus is readily identified by the following characters (Korneyev 2004, 2014a, Kim and Han 2009): presternum with a pair of finger-like lobes (considered a unique synapomorphy supporting monophyly by Korneyev 2014a); antenna with first flagellomere as long as pedicel in dorsal view and arista entirely bare; wing with vein R_{2+3} always with a spur into cell r_{2+3} within apical third and with cells bcu and bm almost entirely bare; femora with two rows of short, spine-like setulae on apicoventral part; oviscape apically with a pair of medioventral hooks. Korneyev (2014b) recognised three subgenera (*Eupyrgota* Coquillett (= *Apyrgota* Hendel; = *Peltodasia* Enderlein), *Taeniomastix* Enderlein and *Asipyrgota* Korneyev) and provided a key to them. The described species reported here belongs in subgenus *Taeniomastix*, which is characterised by a small and slender size (wing length 5-9 mm), scutellum with 1 or 2 pairs of scutellar setae (the basal pair short or absent) and ventral hooks of the oviscape sharp and slender (Korneyev 2014b).

Subgenus *Taeniomastix* Enderlein

Taeniomastix Enderlein, 1942: 113. Type species *T. sumatrana* Enderlein, 1942 [= *Adapsilia griseipennis* Hendel, 1933].

A key to the six described species of subgenus *Taeniomastix* was provided by Korneyev (2014b), who also noted the presence of undescribed species in the Papuan Subregion.

Eupyrgota (*Taeniomastix*) *pictiventris* (Hendel)

(Figs 1-2)

Apyrgota pictiventris Hendel, 1914: 107. Type locality Ceylon [Sri Lanka].

Adapsilia facialis Hendel, 1934: 148. Type locality Taiwan. Syn. Korneyev 2014b: 216.

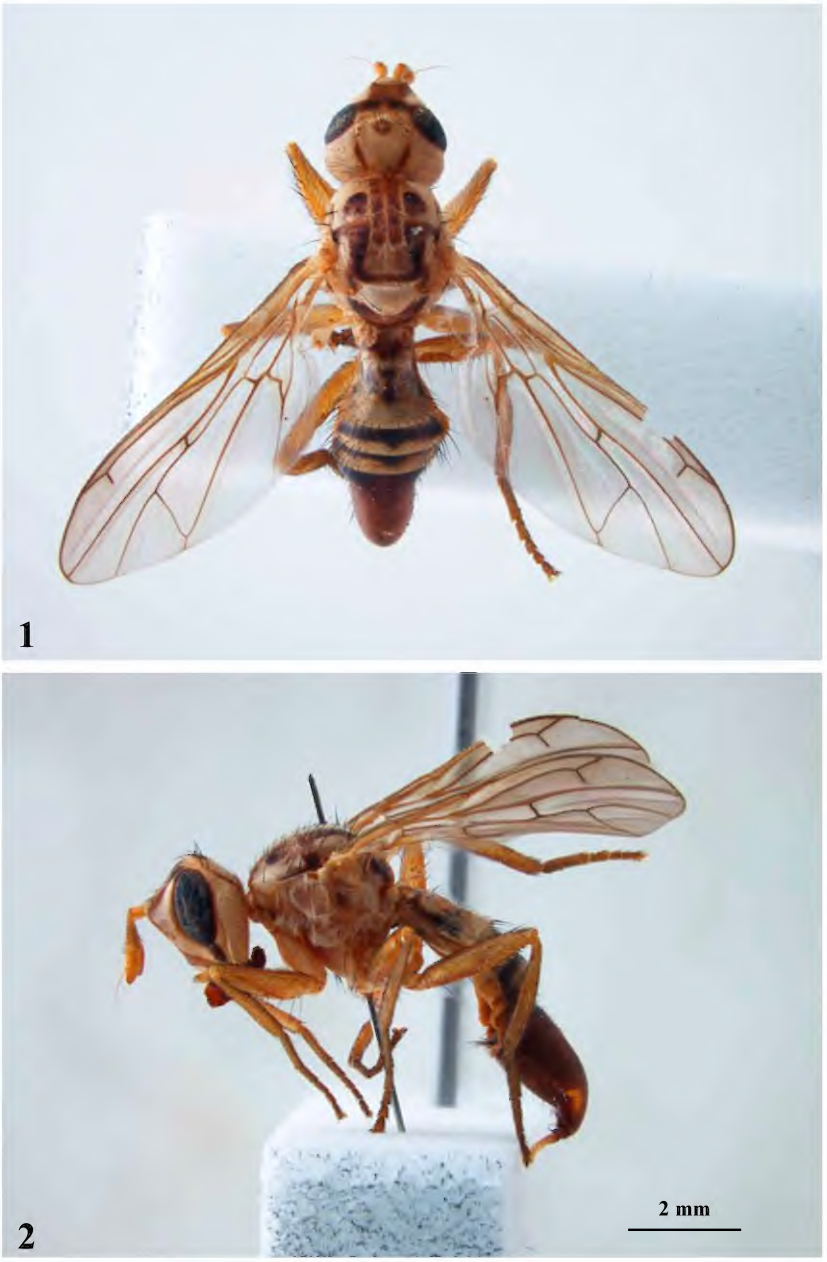
Eupyrgota tigrina Kim & Han, 2000: 227; Kim and Han 2009: 75. Type locality Korea: Gangwon-do, Wonju-si, Maeji-ri. Syn. Korneyev 2014b: 216.

Eupyrgota (*Taeniomastix*) *pictiventris* (Hendel); Korneyev 2014b: 216.

Material examined. AUSTRALIA (QUEENSLAND): 1 ♀, Stratford [Cairns], 16°52.58'S, 145°43.88'E, x.2001, J. Royer, in house (in Qld Dept of Agriculture and Fisheries Collection, Brisbane).

Comments. This species is easily recognised by the generic and subgeneric characters listed above, together with the following combination of specific characters: body yellow with red-brown to black patterns; face with a pair of distinct, triangular ventrolateral spots; a large, elongate subocular spot on gena and a similar pair on occiput on either side of median sclerite; scutum with red-brown to fuscous submedial and black dorsolateral vittae, the latter broadly interrupted at the suture; pale yellow postpronotal lobe, lateral presutural vitta connected to the postpronotal lobe and extending along the suture, isolated lateral postsutural vitta and large prescutellar patch; scutellum pale yellow and bare with a single pair of short apical setae; wing hyaline except for a yellow costal band confluent with vein R_{2+3}; fore femur with 2-7 long posterodorsal setae; oval bare area on anterior face of female mid femur subapical and with fine, dense, pale yellow setulae on ventral edge; abdominal tergites with distinct, black transverse bands. Agreement of the Cairns specimen (Figs 1-2) with both descriptions and colour images (Kim and Han 2009, Korneyev 2014b) indicates that it properly belongs here.

Eupyrgota pictiventris was known previously from Sri Lanka, India, Thailand, West Malaysia, South Korea, Taiwan and the Philippines (Busuanga Island) (Korneyev 2014b). In Korea, almost all known specimens were collected at MV light traps, the species closely resembling a vespid wasp and making a buzzing sound when captured (Kim and Han 2009). Like some other Diptera species (*e.g.* the tephritid *Philophylla fossata* (Fabricius)), it appears to have a wide distribution that includes India, Korea, Taiwan and Australia. Given the species' scarcity and crepuscular habits, the Cairns specimen is considered unlikely to be the result of an artificial introduction.



Figs 1-2. *Eupyrgota* (*Taeniomastix*) *pictiventris* (Hendel), female from Cairns, Qld: (1) dorsal view; (2) lateral view. Wing length 8.0 mm. Photos by Justin Bartlett.

Acknowledgements

We thank Justin Bartlett (Queensland Department of Agriculture and Fisheries, Brisbane) for Figures 1-2, Christine Lambkin and Greg Daniels (Queensland Museum, Brisbane) for confirming the generic identity of the QM specimens and Valery Korneyev (Schmalhausen Institute of Zoology, Kyiv) for discussions and literature.

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LIFE HISTORY NOTES AND OBSERVATIONS ON *PETRELAEA TOMBUGENSIS* (RÖBER) (LEPIDOPTERA: LYCAENIDAE)

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Abstract

New life history notes and observations of *Petrelaea tombugensis* (Röber, [1886]), made at Thursday Island and Cairns, Queensland, are presented and illustrated. *Terminalia muelleri* Benth. (Combretaceae) is confirmed as a host plant, with eggs found laid on flower buds, flowers, flower stems, skeletonised areas on leaves, upper and undersides of mature leaves and on branches. We record for the first time a pupa found in the wild, in debris at the base of the host plant. Interesting adult behaviour is noted with adults of both sexes of *P. tombugensis* observed drinking from the edge of a saltwater swimming pool. Phenotypic variation in adults is also indicated.

Introduction

Petrelaea tombugensis (Röber, [1886]), the Mauve Line-blue butterfly, occurs from the Andaman Islands to mainland New Guinea, the Torres Strait islands and northern mainland Australia. It has a patchy distribution within Australia, being recorded from the Carson River in northern Western Australia (Braby 2015), Coburg Peninsula in the Northern Territory (Common and Waterhouse 1981) and in Queensland from Torres Strait (Müller *et al.* 1998), Lockerbie at the tip of Cape York Peninsula (Braby 2000) and in the Wet Tropics between Cairns and Townsville (Samson and Lambkin 2003).

Once considered a rarity in collections, this species has gone from obscurity, being first discovered on the Australian mainland in 1977 (McEvey 1977) to now being recognised as seasonally abundant where its host plants (*Terminalia* spp: Combretaceae) grow along the coastal fringes of northern Australia.

The life history of *P. tombugensis* was documented by Samson and Lambkin (2003) and this current paper provides additional information on a new host plant and its life history, behaviour and phenotypic variation, based on observations made on Thursday Island and at Cairns in Queensland.

Observations and studies

Host plant studies

Samson and Lambkin (2003) recorded *Terminalia catappa* L. as the host plant and noted only an association with *T. muelleri* Benth. On 16 December 2015, while conducting a butterfly survey along Freshwater Creek near Cairns, one of us (SAB) noticed a *T. muelleri* tree with many lycaenid butterflies flying around it on a trail approximately 50 m from the creek (16°54'31.57"S, 145°42'16.85"E). The tree was *ca* 5 m high and, due to an open canopy in the immediate area, had grown to spread its limbs low and

wide, which made examination of the branches and leaves convenient. There were more than 50 butterflies, identified as *P. tombugensis* (Figs 1-2), flying around the tree. The next day, a closer inspection of the flowers revealed many early stages (*i.e.* eggs and larvae), which were collected and reared in captivity in Cairns. Adults reared were identified as *P. tombugensis*, thus confirming *T. muelleri* as a host plant.

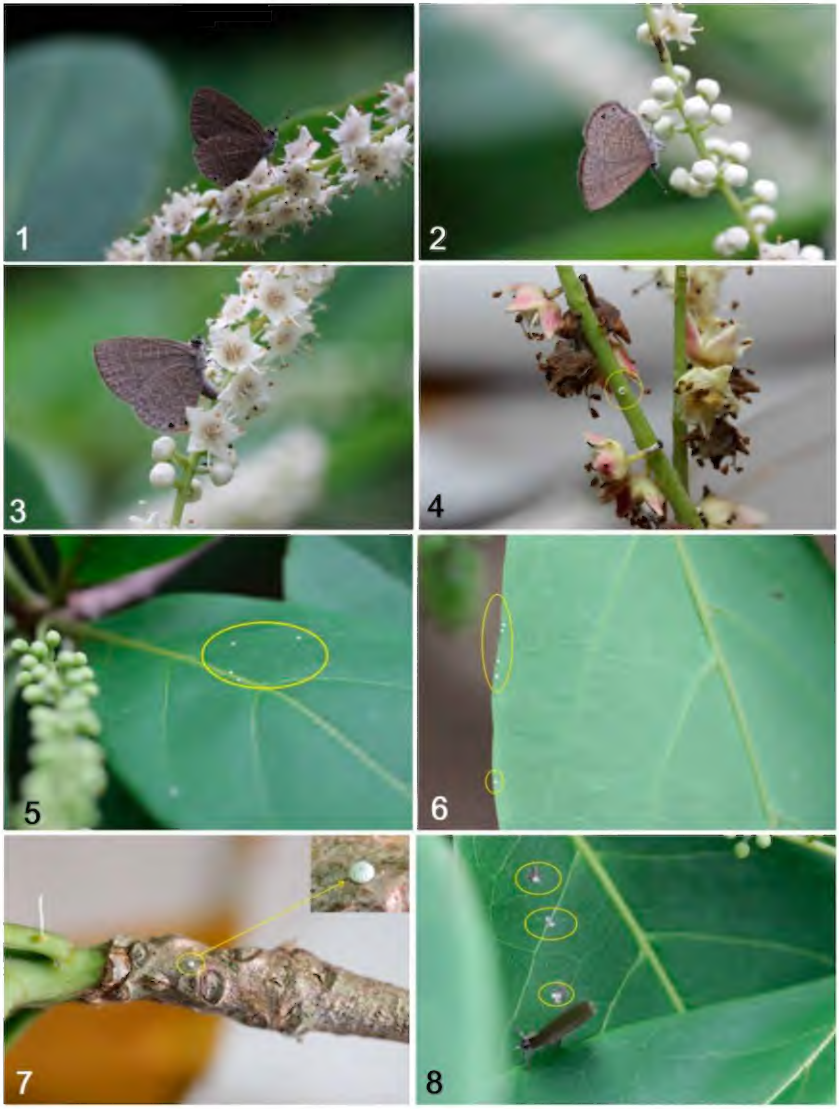
Life history studies

Samson and Lambkin (2003) discovered eggs of *P. tombugensis* laid singly on flower buds of *T. catappa*. They also described and illustrated the final instar larva and pupa; however, the natural pupation site was not known to them. During our survey we found eggs laid on flower buds, flowers and stems (Figs 3-4) of the host plant and, in addition, on the upper and undersides of mature leaves (Figs 5-6). Eggs laid on the underside of leaves were predominantly laid along the leaf margin (Fig. 6) but were also laid on the branches (Fig. 7) and in the skeletonised sections of leaves (Fig. 8).

Despite some eggs being laid on leaves, larvae fed exclusively on flowers. Larvae were so abundant on the tree that up to four larvae at a time could be found on each flower; however, it was more common to find just a single larva per flower stem. As the pupation sites of this species in the wild had not been documented, we searched flower stems, leaves, branches, under bark on the tree and through dead leaf litter caught in the tree. We also searched adjacent trees that were in contact with the host tree and made a superficial search of the leaf litter at the base of the host tree and radially out from the trunk to the edge of the canopy. We did not find any pupae, despite there being hundreds of larvae on the tree and finding many final instar larvae just days before.

The host tree was attended by ants of various species, including green tree ants, *Oecophylla smaragdina* (Fabricius). We suspected that the mature larvae of *P. tombugensis* were being preyed upon by the green tree ants on their way to pupation at the base of the tree, as the ants were prolific around its trunk and branches. To test this hypothesis, we carefully removed a final instar larva from a flower stem and then placed it on the trunk of the tree among a trail of green tree ants. To our surprise, the ants ignored the larva and allowed it to crawl back to a flower to continue feeding. We repeated this exercise several times with the same result. Based on this, we discounted green tree ant predation as a possible reason for the lack of pupal activity around the host tree.

We decided to gather more insight into their pupal habits by observing the larvae we had in captivity. When reared in containers with only flower stems and paper towelling, we found that the larvae would generally pupate under the paper towelling and occasionally silk themselves to a group of dead flowers. However, when a dead leaf was introduced to the container, the



Figs 1-8. (1-2) Adults of *Petrelaea tombugensis* feeding on flowers of *Terminalia muelleri* in Cairns, Queensland: (1) male; (2) female; (3) adult female ovipositing while feeding on a flower; (4) eggs laid on stem of flower; (5) eggs laid on the leaf upperside; (6) eggs laid on the leaf underside; (7) egg laid on branch [inset = close-up of egg]; (8) eggs laid within skeletonised areas of upperside of leaf.

larvae showed a preference for pupation in naturally occurring, curled up shelters of the dead leaf. We then introduced a piece of tree bark and a hollowed twig in addition to the dead leaf, after which the larvae pupated gregariously under the tree bark and in the hollowed twig in preference to the dead leaf. With this information, we undertook a more focussed and systematic survey of the area around the base of the host tree, carefully hand-picking and examining each dead leaf, twig, branch and piece of bark from underneath the tree (Fig. 9). We eventually discovered a single pupa of what appeared to be *P. tombugensis* (Fig. 10). The pupa was collected and a few days later a female *P. tombugensis* emerged.

Figs 9-10. (9) Searching for pupae of *Petrelaea tombugensis* at the base of *Terminalia muelleri* in Cairns, Queensland; (10) pupa (circled) of *P. tombugensis* discovered on decomposing timber at base of the host plant.

While we eventually found a single pupa at the base of the host tree, we were expecting to find significantly more given the large number of larvae on the tree. The following season, in 2016, we found *P. tombugensis* adults and larvae to be abundant again around the same host tree. Given that pupae preferred to pupate under bark in captivity, we decided to place several 'bands' around the trunk and branches of the tree. The bands were made from ribbed marine grade carpet, a material the authors had used previously for collecting pupae of several lycaenid species. The bands were placed in several locations, including close to the flowers near the ends of branches, towards the centre of the tree on larger branches and as a large band around the entire trunk at the base of the tree. These bands were checked at the end of the 2016 season and no pupae of *P. tombugensis* were found. The bands were left on the tree for another season but, at the end of the 2017 season, once again no pupae were found. We therefore concluded that banding is not a successful method of obtaining pupae of *P. tombugensis*, suggesting that further field work is required to better understand the preferred natural pupation sites and natural predators.

Figs 11-13. *Petrelaea tombugensis*: (11) adult male foraging around pool in November at 07:40h; (12) depiction of adult drinking on the wing; (13) phenotypic variation within adult females.

Behavioural studies

Adult butterflies were observed from November to February, flying down from a large *T. catappa* tree (*ca* 25 m high) in the garden of MH to sip salts from the surrounds of a saltwater swimming pool from early morning to mid-afternoon (Fig. 11). This phenomenon had been reported previously by Parsons (1998) but he only reported males exhibiting this behaviour, whereas in Cairns we observed equal numbers of males and females doing so. Some adults were observed flying over the pool and momentarily dunking their proboscis (and perhaps entire body) into the water of the pool while on the wing (Fig. 12). This behaviour has also been recorded at the same site in Cairns for several other species of Lycaenidae, including *Nacaduba berenice* (Herrich-Schäffer, 1869), *Prosotas nora* (C. Felder, 1860), *Prosotas dubiosa*

(Semper, [1879]), *Ionolyce helicon* (C. Felder, 1860), *Catochrysops panormus* (C. Felder, 1860) and *Sahulana scintillata* (T.P. Lucas, 1889) (unpublished data).

Phenotypic variation

Phenotypic variation within *P. tombugensis* has not been recorded previously. In our study, we found males and females of *P. tombugensis* from Cairns and Thursday Island to be variable in wingspan, with males generally larger than females. In females, the extent of blue on the upperside of both wings is highly variable, with the blue sometimes absent (Fig. 13).

Acknowledgements

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A STRIKING NEW SPECIES OF *PARAPODACANTHUS* BROCK (PHASMIDA: PHASMATIDAE) FROM SOUTHEASTERN QUEENSLAND

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Abstract

Studies on the rarely reported Australian genus *Parapodacanthus* Brock have revealed a striking new species from Springbrook, Lamington Plateau and Cunningham's Gap in southeast Queensland. It is described and figured, including the egg, as *Parapodacanthus ailaketoae* **sp. n.** Keys are provided to compare it with the only other species in the genus, *P. hasenpuschorum* Brock, 2003 from north Queensland. Additional localities are recorded for the latter species.

Introduction

The genus *Parapodacanthus* Brock, 2003, with its single described species, *P. hasenpuschorum* Brock, 2003, has rarely been mentioned in the literature and specimens are scarce in collections. Only one old specimen resided in collections prior to living specimens of this colourful species being detected in northern Queensland in the 1990s and making it feasible to describe the new genus and species.

Although phasmids are understudied, enthusiasts of the Australian phasmid fauna can refer to Brock and Hasenpusch (2009), which has encouraged some further studies. The first author was initially contacted in 2013 by Dr Aila Keto, who was keen on studying stick insects in her local area (Springbrook Plateau, SE Queensland) with the help of a group of dedicated volunteers. Subsequently, in January 2014 they discovered a *Parapodacanthus* specimen of uncertain identity. Springbrook is a rich and diverse mountain plateau rising to 1000 m, with flora and fauna that establishes it as an important Gondwanan remnant (Crisp and Crisp 2006, Kitching *et al*. 2010) and part of the Gondwana Rainforests of Australia's World Heritage Area. It lies on the border between Queensland and New South Wales, 1500 km south of the known range of *P. hasenpuschorum.* It has 2480 ha of National Parks, many scenic attractions and is much visited by tourists from the nearby Gold Coast only 45 minutes drive away, as well as by naturalists and biologists. The presence of an undiscovered *Parapodacanthus* species there thus came as a surprise. Both authors and Helen Brock visited in February 2016 in what proved to be a successful effort to find live material. The first author, with Noelene Tweed, visited again in February 2017 and obtained more material. The species proved to be distinct and is described here as *Parapodacanthus ailaketoae* **sp. n.**

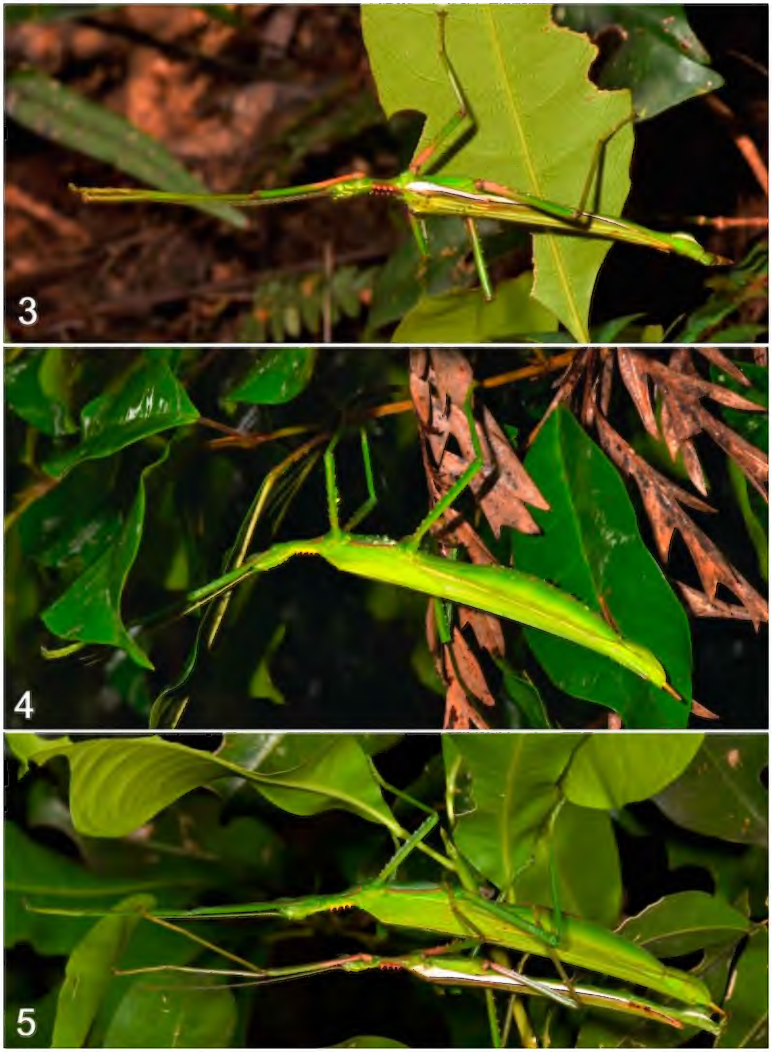
The following abbreviations have been used for depositories: *ANIC* – Australian National Insect Collection, Canberra, Australia; *MHNG* – Muséum d'histoire naturelle, Geneva, Switzerland; *PDB* – P.D. Brock collection, United Kingdom; *QM* - Queensland Museum, Brisbane, Australia.

Key to adults of *Parapodacanthus*

Mesonotum with four pairs of spine-like tubercles; front pair much longer, curved anteriad and laterad, the others slanting outwards; posterior pair shorter than preceding pairs. Forewings of both sexes with bold cream markings or stripes. Body length larger: ♂ 83 to 93 mm, ♀ 100 to 119 mm. Distribution: northern Queensland (Figs 1-2) ……. *P. hasenpuschorum* Brock

Mesonotum with four pairs of similar-sized, spine-like tubercles; front pair slightly longer, curved anteriad. Forewings plain (female) or with less distinct cream stripes (male). Body length smaller: ♂ 71 to 78 mm, ♀ 89 to 90 mm. Distribution: SE Queensland (Figs 3-5) ……..... *P. ailaketoae* **sp. n.**

Figs 1-2. *Parapodacanthus hasenpuschorum*, living adults: (1) male; (2) female. (Photos by Buck Richardson (1) and Paul Brock (2)).



Figs 3-5. *Parapodacanthus ailaketoae*, living adults: (3) male paratype from Springbrook; (4) female holotype from Lamington; (5) mating pair from Springbrook (paratypes). (Photos by Paul Brock).

Key to eggs of *Parapodacanthus*

Slightly hairy, rugged capsule; knob-like capitulum on a short stalk; micropylar plate low down (Fig. 7) ……..... *P. hasenpuschorum*

Finely hairy capsule; small knob-like capitulum on a longer stalk; micropylar plate near centre (Fig. 6) ……..... *P. ailaketoae* **sp. n.**

Figs 6-7. Eggs of *Parapodacanthus* spp: (6) *P. ailaketoae,* from holotype, lateral view (left) and dorsal view (right); (7) *P. hasenpuschorum,* lateral view (right) and dorsal view (left). (Photos by Paul Brock).

Parapodacanthus **Brock**

Parapodacanthus Brock, 2003: 32. Type species *Parapodacanthus hasenpuschorum* Brock, 2003, by original designation.

Parapodacanthus: Otte and Brock 2005: 252; Brock and Hasenpusch 2009: 177.

Generic characteristics (slightly revised from Brock 2003). Closely related to *Podacanthus* Gray, but easily distinguished by the presence of large spine-like tubercles on the mesonotum, in addition to differences in egg structure.

Description. Medium sized, large winged Tropidoderini. Head slightly longer than wide, eyes large; three ocelli present. Antennae long but shorter than length of foreleg. Scapus slightly broader than remaining segments. Pronotum slightly longer than head, with central impression. Mesonotum short, just over 1.5 times length of pronotum, with four pairs of large brown spine-like tubercles, sometimes slanting and variable in length. Lateral margins of meso- and metathorax with series of small tubercles. Metathorax with small tubercles ventrally. Forewings long and slender; hind wings large with darker veins. Legs moderately long and slender. Fore femora smooth except for apical spine, mid and hind femora spiny. Tarsi of modest length. Abdomen slender, in ♂ anal segment twice length of 9th segment, split into large lobes, broad dorsally then narrowing, ending in a club. Lobes form an expanded, circular arch-like structure. Subgenital plate swollen, raised in centre, reaching beyond 9th abdominal segment. In ♀ operculum long and narrow, rounded or tapered at tip, about or extending beyond end of anal segment. Hind margin of anal segment boldly triangular incised; supra-anal plate visible. Cerci longer than anal segment, broadened and leaf-like, slightly pointed at tip; overlapping or incurved.

Egg. Small, oval, with a capitulum; capsule conspicuously hairy and not ridged. Micropylar plate small, either central or lower. In *Podacanthus*, eggs are large, oval or elongate; capsule not hairy, with numerous raised ridges.

***Parapodacanthus hasenpuschorum* Brock**

[Hasenpusch Family Stick-insect]

(Figs 1-2, 7)

Parapodacanthus hasenpuschorum Brock, 2003: 32, figs 46-53, 60-62. *Holotype* ♂, AUSTRALIA (QUEENSLAND): Stone Creek, Garradunga, Innisfail, 19.i.1996, J. Hasenpusch (In QM, T144272). Paratypes of both sexes are deposited in ANIC, QM (T144273-T144285), MHNG and PDB.

Parapodacanthus hasenpuschorum: Otte and Brock 2005: 252; Brock and Hasenpusch 2009: 134; Velonà *et al*. 2015: 458.

Distribution (Fig. 17). Northern Queensland: Cairns, Garradunga, Kuranda; seldom recorded. Also recently found in Davies Creek National Park in December 2015 (Beth Ripper pers. comm. 2016). A male was photographed 5 km NE of Kuranda by Buck Richardson in 2017 (Fig. 1).

***Parapodacanthus ailaketoae* sp. n.**

[Aila Keto's Stick-insect]

(Figs 3-6, 8-16)

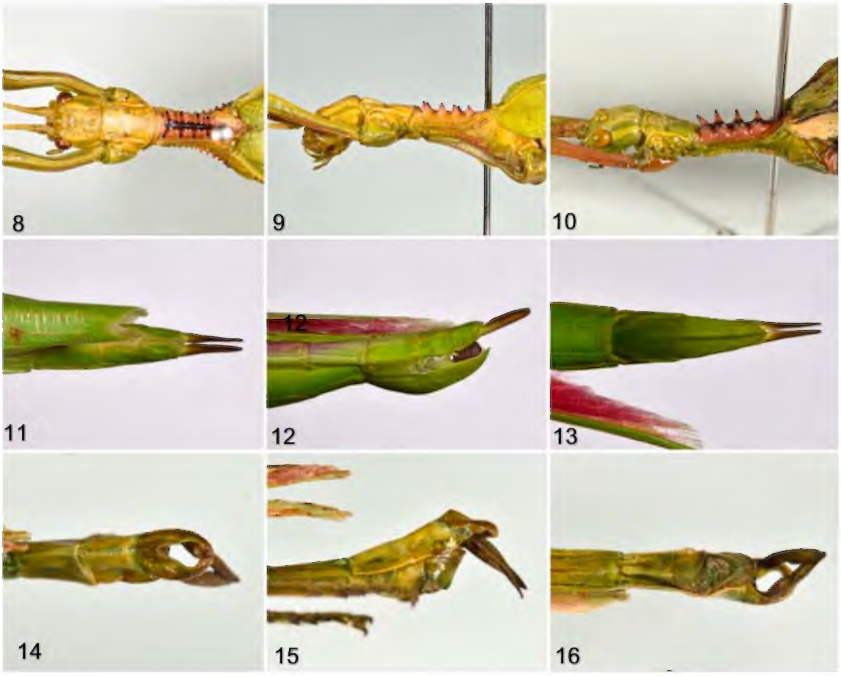
Types. Holotype ♀, QUEENSLAND, Binna Burra, Lamington NP, 28.194°S, 153.187°E, 13.ii.2016, P.D & H. Brock & G. Monteith, *c*.762 m, DNA project PB0226 (QM, T244503). *Paratypes*: QUEENSLAND: 1 ♂, Springbrook, Ankida Nature Refuge, 28.182°S, 153.258°E, 11.ii.2016, P.D & H. Brock, G. Monteith *et al*., *c*.646 m, DNA project PB0225 (QM, T244506); 2 ♂♂, same locality but 28.182°S, 153.257°E, 2015, 650 m, A. Keto and K. Scott (QM, T244504-5); 1 ♂, same locality, 3.ii.2017, P.D Brock and N. Tweed, DNA project PB0140 (QM, T239668); 1 ♂, 1 ♀, Springbrook, Apple Tree Park, 28.166°S, 153.259°E, 4.ii.2017, P.D Brock and N. Tweed, DNA project PB0146/147 (QM, T239669-70); 1 ♀, Cunningham's Gap, SE Qld, 30Mar1995, D.G. Knowles, (QM, T244507, ex coll. Anthony Hiller). Eggs also deposited in QM [not paratypes].

Description. Attractive leaf green with some brown markings, medium sized insect of glossy appearance, with four pairs of spine-like tubercles on mesonotum and dark pink hindwings.

Female (Figs 4-5, 8-9, 11-13). Head: green, with yellowish lines; slightly longer than wide; three ocelli present. Antennae long, with 27 segments; basal segment broad. Thorax: pronotum green, slightly longer than head, with central impression. Mesonotum slightly longer than pronotum, with four pairs of darker-tipped brown spine-like tubercles of equal size, the front pair slightly curved anteriad; a darker longitudinal line runs through the centre between spines; remainder of mesonotum green. Metanotum longer than mesonotum; green. Lateral margin of meso- and metathorax with series of conspicuous brown tubercles, variable in size and spacing. Ventral surface of metathorax whitish, with tubercles. Abdomen: green with middle part reddish brown; rather plump when laden with eggs. Length of 8th abdominal segment about combined length of 9th and 10th (anal) segments. End of anal segment

boldly triangularly incised, supra-anal plate visible, rounded at tip, which extends beyond anal segment. Operculum tapered to a triangular tip, reaching about end of anal segment. Cerci elongate, broader at base, tapered to a rounded tip. Wings: forewings long, much broader than mesonotum, tapered to a rounded tip, green with yellowish veins; pre-anal part of wings the same colour, inner margin transparent/reddish. Hind wings dark pink with darker pink veins. Legs: green, elongate, slightly hairy; mid and hind femora with up to eight fairly evenly spaced serrations on ventrolateral carinae and an apical spine; tibiae smooth; tarsi of modest length.

Male (Figs 3, 5, 10, 14-16). Apart from being slenderer, similar in general appearance, although fore and hind wings have a broad cream marginal band, followed by a thick mauve band with a narrow greenish yellow vein between. Anal segment a little longer than 9th abdominal segment, split into two large lobes. Poculum rounded at tip, reaching end of anal segment.



Figs 8-16. *Parapodacanthus ailaketoae,* details of head, thorax and abdominal apex of female holotype and male paratype: (8) female head and thorax, dorsal view; (9) the same, lateral view; (10) male head and thorax, lateral view; (11) female abdominal apex, dorsal view; (12) the same, lateral view with undeposited egg visible; (13) the same, ventral view; (14) male abdominal apex, dorsal view; (15) the same, lateral view; (16) the same, ventral view. (Photos by Paul Brock).

Egg (Fig. 6). Small, brown, oval capsule with darker banding and a mushroom-like capitulum; capsule conspicuously hairy and not ridged. Micropylar plate small, about central but partial stalk below, not reaching base of capsule.

Measurements (in mm) for 5 males and 2 females. *Length of body:* female 89-90, male 71-78. *Head*: female 4.5, male 3-3.5. *Antennae*: female 39-41, male 41 (tips often broken off). *Pronotum*: female 4.8, male 3.5. *Mesonotum*: female 5, male 4.5-5. *Metanotum*: female 14, male 9-10. *Median segment*: female 6, male 5-6. *Forewing*: female 26-28, male 14-17. *Hind wing*: female 65-73, male 47-54. *Femora, fore, mid, hind*: female 20-22, 15-16, 21-22, male 19-20, 13-14, 17-19. *Tibiae, fore, mid, hind*: female 19.5-23, 14-15, 19-21, male 18-19, 11-12, 16-18. *Cerci*: female 4, male 4. *Eggs*: Capsule length 3, width 1.8, height 2.

Note. As is usual in phasmids, there can be variation in colour and spines within a species. However, *Parapodacanthus* species appear to be uniform in colour and only the spines on the mesonotum readily distinguish the new species from *P. hasenpuschorum*, although there are further differences in colour, genitalia (male lobes much larger in *P. hasenpuschorum*, with incurved cerci) and eggs. Detailed photographs will be uploaded to *http://phasmida.speciesfile.org*

Etymology. Named after Dr Aila Inkeri Keto AO, founder and President of the Australian Rainforest Conservation Society, for her outstanding environmental and conservation work, particularly for her struggle for declaration of the two rainforest-centred World Heritage Areas in Australia where *Parapodacanthus* occurs. It is fitting that this spectacular new species had remained undetected, almost on her doorstep in Springbrook.

Distribution (Fig. 17). The type series is from southeastern Queensland, where it is known from two well known and adjacent localities, *viz*. Lamington NP and Springbrook, but is likely to be found elsewhere in the area and at least in parts of northern New South Wales. David Rentz (pers. comm, 2017) forwarded a photograph that had come to his attention showing a nymph, taken in December 2016 near Dorrigo, New South Wales. An adult male was photographed at Binna Burra on 4 November 2016, another at Apple Tree Park, Springbrook on 4 January 2017 (Ross Coupland pers. comm.). A mating pair was observed at the latter locality by Brock and Tweed on 4 February 2017 (Fig. 5).

As this paper was being finalised, a 1995-collected female from Cunningham's Gap was located in the private collection of Anthony Hiller. This is an elevated rainforest locality 80 km WNW of Lamington/ Springbrook and connected by a continuous chain of similar mountain habitats. This beautiful but cryptic species probably occurs throughout these intervening areas.

Habitat and food plants. At Springbrook the species was taken at three different sites in tall wet sclerophyll forest with a dense understorey of rainforest plants and was feeding at one site on *Schizomeria ovata* D. Dom (Cunoniaceae). At Binna Burra it occurred in pure rainforest and was feeding on *Vitex lignum-vitae* A. Cunn. ex Shauer (Lamiaceae). All localities are comparatively low altitude (570-815 m) within the region and it is notable that it has not been taken at the higher (up to 1000 m), southern end of Springbrook, where collecting has been more intensive. It has been noted as adults so far at least between November and March.

Fig. 17. Maps with all recorded localities for *Parapodacanthus* spp shown as red spots. Main map shows overall distribution in eastern Australia with the unconfirmed locality of Dorrigo shown. Map A shows detailed view for *P. hasenpuschorum* in northern Queensland. Map B shows detailed view for *P. ailaketoae* in the mountains along the Queensland/New South Wales border.

Discussion

The 1500 km disjunct distribution of the two species of this endemic Australian rainforest genus, between the Wet Tropics of northern Queensland and the Border Ranges of southern Queensland, indicates that the genus will almost certainly date from the Cretaceous-Palaeogene (145-23 mya), when mesic rainforests were continuous and widespread in eastern Australia.

As a result of the subsequent dissection of the continuous rainforest into the present archipelago of remnant refugia along the eastern seaboard of Australia, vicariance will likely be the driving force behind separation of the two species. This pattern of speciation in eastern Australia has been reviewed recently by Bryant and Krosch (2016).

The relatively few records in the literature and disjunct distribution of *Parapodacanthus* in Queensland are similar to the distribution of two *Onchestus* Stål, 1877 species, also uncommon in Australia and known from few records (Brock and Hasenpusch 2006), although Beth Ripper (pers. comm. 2016) found *O. rentzi* Brock & Hasenpusch, 2006 at several unreported sites in northern Queensland. A third species of *Onchestus* from central Queensland will shortly be described by Brock and Hasenpusch, who are also describing other species of phasmids collected in Springbrook. The apparent scarcity of species often relates to limited interest in phasmids and/or the fact they are nocturnal and rarely searched for at night, so the true distribution might be much more extensive than recorded and the presence of *Parapodacanthus* in one of the central Queensland refugia, such as the Eungella Range, is quite feasible. Initial results of DNA barcoding of the Australian phasmid fauna are given in Velonà *et al*. (2015); further work is in progress, including DNA barcoding of *Parapodacanthus*.

Other phasmids readily found in a small part of Springbrook include large undescribed taxa (descriptions in progress), indicating that this is an important area, considered by the authors to be one of the best rainforest sites so far known for this order. Springbrook is part of a notable long-term project (*www.springbrookrescue.org.au*), coordinated by Aila Keto and Keith Scott, to recover a more viable World Heritage Area. A number of volunteers help with this inspirational project.

Acknowledgements

We wish to thank the following contacts for their assistance and/or observations: primarily Aila Keto and Keith Scott for alerting the authors to this species, arranging our stay in Springbrook and helping find a live specimen in the daytime on 11 February 2016, by taking the authors to a likely site where a male was spotted by Declan Baericke, Aila's helper on that day. We were also able to view photographs of phasmids taken over several years by local volunteers. Thanks are also due to Helen Brock (on the 2016 visit to Springbrook), Ross Coupland, Jack Hasenpusch, David Rentz, Beth Ripper and Noelene Tweed (2017 visit to Springbrook with PDB). Buck Richardson of Kuranda kindly gave permission to use his excellent image of *P. hasenpuschorum* (Fig. 1). The maps in Fig. 17 were prepared using the mapping facility on the Atlas of Living Australia website. Anthony Hiller kindly allowed deposition of the Cunningham's Gap specimen from his collection in the Queensland Museum.

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NOTES ON THE GENUS *NOLA* LEACH (LEPIDOPTERA: NOLIDAE: NOLINAE) FROM FIJI, WITH THE DESCRIPTION OF A NEW SPECIES

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Abstract

The genus *Nola* Leach in Fiji is reviewed and a new species, *N. savura* **sp. n.**, is described. The placement of existing species in the genus is confirmed based on the current generic definition. These species are fully described and illustrated to augment the brief descriptions presently available.

Introduction

The genus *Nola* Leach consists of small, mostly cryptically coloured moths, mainly white or buff with dark brown or black markings. Robinson (1975) discussed *Nola* from Fiji and Rotuma. He included five species: *N. insularum* (Collenette), *N. samoana* (Hampson), *N. fijiensis* Robinson, *N. lichenosa* Robinson and *N. transversata* Robinson, the last three described as new. He provided drawings of the forewing pattern, a single valve from the male genitalia and the male ventral abdominal spines. He noted that *N. samoana* only occurred on Rotuma, a small group of islands situated approximately 650 km north of the main Fiji group. The present study includes only this main group; hence *N. samoana* is not considered.

This study found 178 specimens that could be assigned to *Nola,* including examples of all four previously recorded species. Adults are illustrated along with male and female genitalia, where available. Their placement in the genus *Nola* is confirmed. Three specimens were found not to belong to the existing species and are described as *Nola savura* **sp. n.**

Materials and methods

A regular programme of light trapping was carried out during the period 1991-1998. This was used to sample the moth fauna at various lowland forest locations in Eastern Viti Levu (with approximate geographical coordinates): the provinces of Serua (-18°09′, 178°01′), Namosi (-18°06′, 178°10′) and Tailevu (-17°55′ 178°30′) and in the general Suva area (-18°04′, 178°26′ and -18°09′, 178°26′). A small number of visits were also made to Cakaudrove province in Vanua Levu (-16°25′, 179°54′). These locations ranged in altitude from sea level to 200 m.

Recording also took place in montane forest in Naitasiri province (-17°43′, 178°01′) at an altitude of 900 m. A battery powered trap was employed, using a 6W actinic tube as the light source. This allowed easier access to more remote locations. A small number of further visits were made up to 2013.

Systematics

The Nolinae have long been considered a subfamily of either the Arctiidae or Noctuidae. Holloway (1998) grouped the Nolinae with the Sarrothripinae, Chloephorinae and Camptolominae to form the family Nolidae, which he retained in the Noctuoidea. The separation of the Nolidae was confirmed by Kitching and Rawlins (1998).

The molecular phylogeny of Zahiri et al. (2011) confirmed the monophyly of the Nolidae as a family within the Noctuoidea and this classification is followed here. The large majority of species are contained in the subfamilies Nolinae and Chloephorinae (with the previous Sarrothripinae included as the tribe Sarrothripini). Some other very small subfamilies have also been included. The generic definition of *Nola* followed here is that of Holloway (2003), with further discussion below.

Family Nolidae

Subfamily Nolinae

Genus *Nola* Leach, [1815]

Type species *Pyralis palliolalis* Hübner (= *Tinea cucullatella* Linnaeus).

Holloway and Miller (1995) discussed the current definition of *Nola* and proposed a stricter definition that is most clearly defined on features of the male genitalia. Holloway (2003) discussed *Nola* and several related genera in the Bornean context based on this definition, in particular the loss of or extreme reduction of the uncus and the deep cleavage of the valves into two longitudinal lobes. Based on this definition, he moved eight of the Bornean species from *Nola* to *Manoba* Walker. These species all have simple valves in the male genitalia. Holloway (2003) noted that *Nola* as currently used is extremely widespread and diverse, with several hundred species worldwide, but its true extent cannot be judged until species are reviewed based on the restricted definition. In this study, the existing Fijian species are reviewed in the context of *Nola sensu stricto*.

The five Fijian species examined all fit the general colour and pattern of typical *Nola* species mentioned above. One species (*N. fijiensis*) shows considerable variation in wing pattern and four examples are illustrated (Figs 1-4). The other four species are much more consistent in markings. In all species the male genitalia, notably the absence of an uncus and the deep cleavage of the valves, confirm their placement in *Nola.* With the uncus absent, the gnathos is prominent, extending to approximately half the length of the valves. The aedeagus varies from long and narrow to shorter and stouter. Two species have a single cornutus, the other three having none. The female genitalia are very flimsy. For the three species for which they are available they are rather similar, with an absence of structure in the region of the sterigma. The ductus bursae exhibits limited variation between species.

The bursa is round in shape, with a signum present in only one species, *N. lichenosa*. Based on these features and their wing patterns, there appears to be a close relationship between *N. fijiensis* and *N. insularum* and separation of these two species can be difficult in some cases without examination of the genitalia. This is discussed further under the relevant species.

Redescriptions are provided for *N. fijiensis, N. lichenosa* and *N. transversata* as Robinson's (1975) descriptions are very brief and omit many important diagnostic features; *N. insularum* is also redescribed for completeness. In the discussion of individual species, the diagnostic features are to be interpreted in the Fijian context. No sexual dimorphism in wing pattern was observed, so it was considered unnecessary to illustrate both sexes.

***Nola fijiensis* Robinson, 1975**

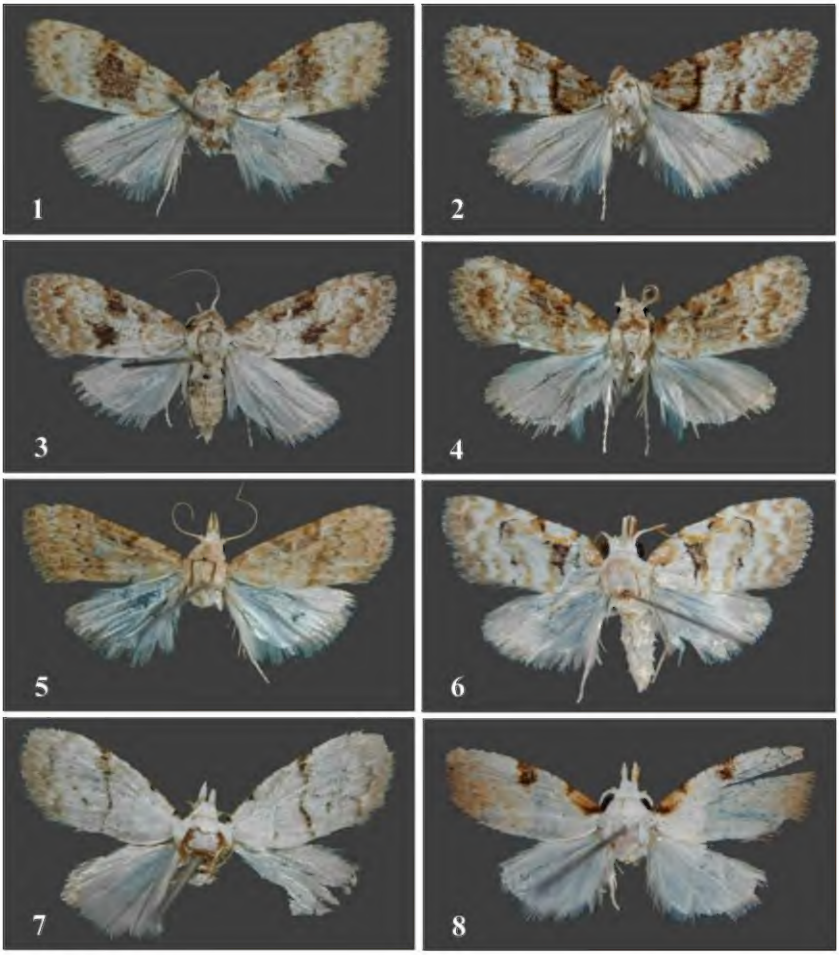
(Figs 1-4, 9, 14)

Material examined. 145 specimens from all localities, but only 6 from suburban Suva. By far the commonest of the Fijian *Nola* species.

Redescription (all forms: Figs 1-4). Head: vertex and labial palpi pale buff. Thorax: same colour as head, with some darker shading dorsally. Wingspan 11-14 mm. Forewings: costa slightly bowed; termen convex; apex slightly obtuse; ground colour white or pale grey, with more or less buff suffusion; markings brown to dark brown; antemedian fascia from costa at one quarter to dorsum at one third, in the form of a somewhat diffuse line with projection distad at R1; postmedian fascia from costa at three quarters to dorsum at two thirds, in the form of a serrated line; curved distad between one quarter and three fifths; dorsal two fifths broader and darker; subterminal fascia from costa at four fifths to dorsum just before tornus, in the form of a somewhat broader and diffuse serrated line; a single projection distad at one quarter and two around one half broader and darker coloured, giving the impression of a series of three spots; preceded by buff shading on dorsal two thirds; terminal fascia a series of paler brown, square spots; irregular buff shading between the subterminal and terminal fasciae. Hind wings uniform whitish. Abdomen pale grey, suffused buff anteriorly.

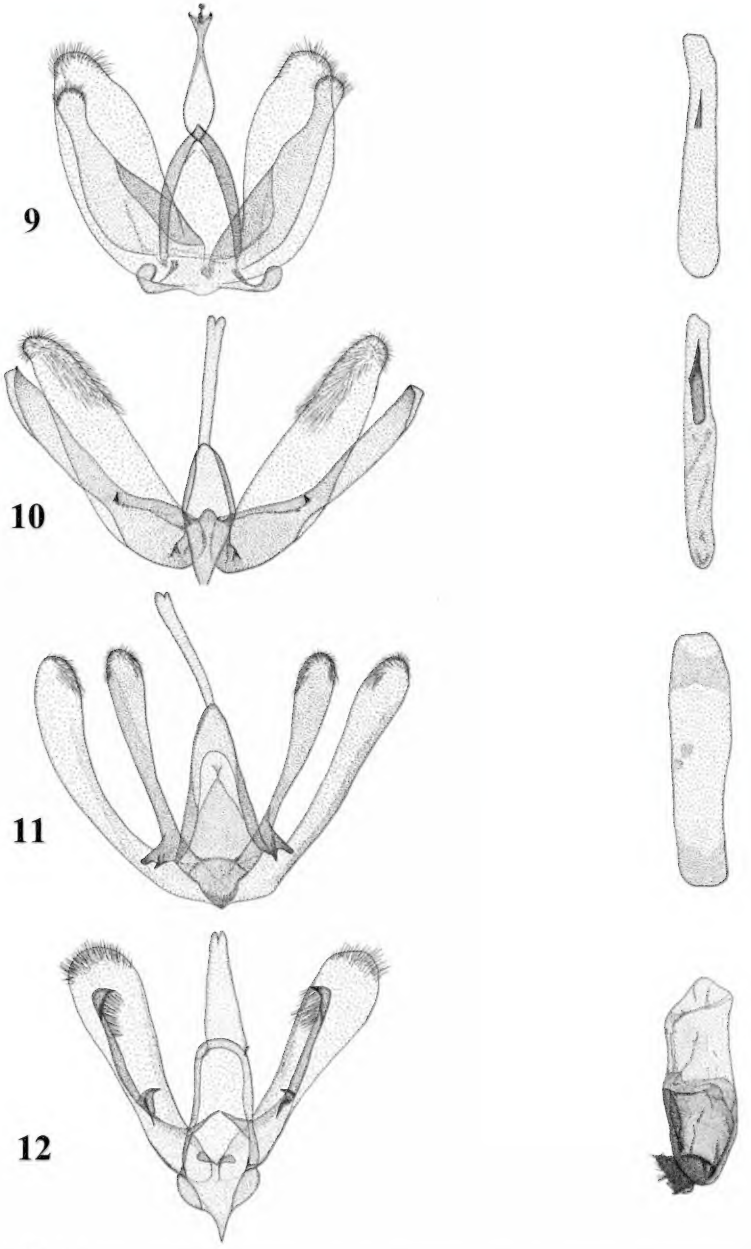
Male genitalia (Fig. 9): valves deeply divided into two lobes; dorsal lobe 2-3 times the width of the ventral lobe and slightly longer; valves lacking processes; uncus absent; gnathos approximately half as long as valves, narrow with basal two thirds swollen and a striking, trifurcate tip; aedeagus narrow, with a single straight, narrow cornutus approximately one fifth of the length of the aedeagus.

Female genitalia (Fig. 14): ductus bursae with a slightly swollen and lightly sclerotised section approximately one quarter of its length shortly before it widens to bursa; bursa copulatrix round and featureless.

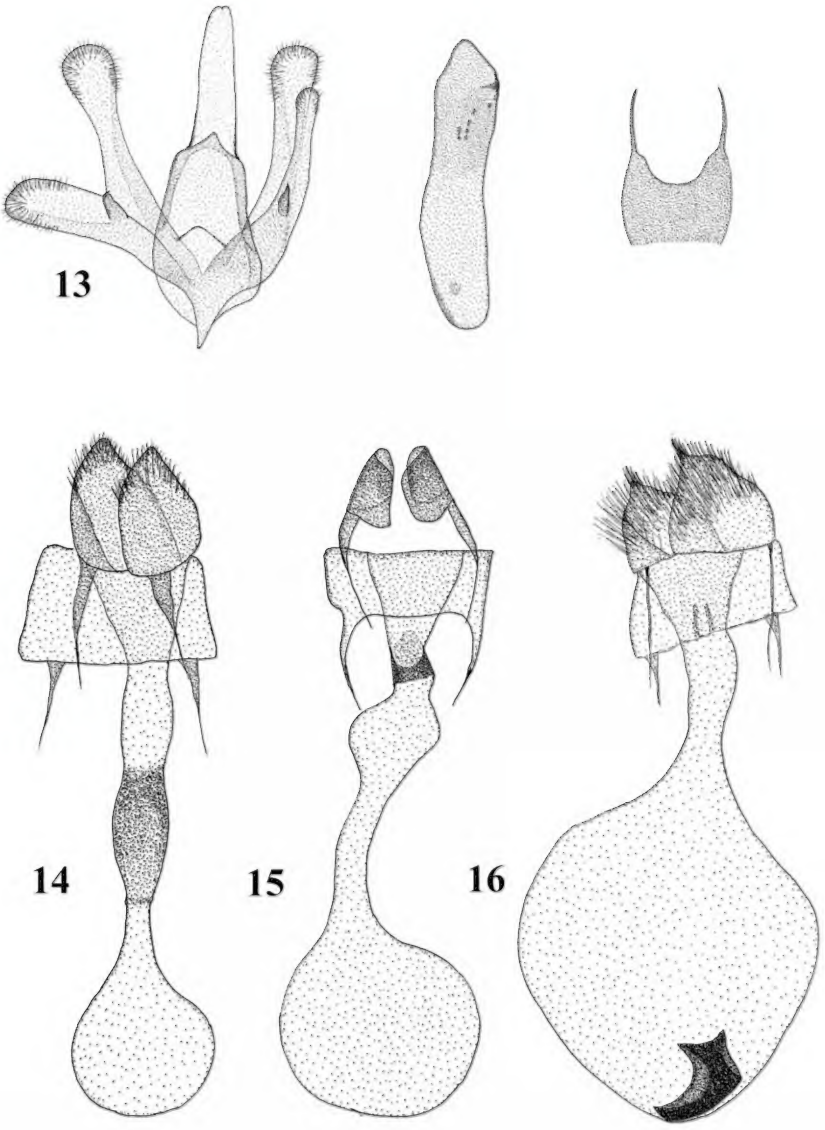


Figs 1-8. *Nola* spp: (1-4) *N. fijiensis* Robinson; (5) *N. insularun* (Collenette); (6) *N. lichenosa* Robinson; (7) *N. transversata* Robinson; (8) *N. savura* **sp. n.**, holotype.

Variation. The above description includes the features common to all forms, which are characteristic of *N. fijiensis.* The wide range of forms recorded can be assigned more or less to those illustrated in Figs 1-4: Fig. 1 – area from antemedian fascia to shortly before postmedian fascia more or less shaded dark brown; Fig. 2 – basal area extending to antemedian fascia more or less shaded brown and antemedian fascia wider and darker; Fig. 3 – subrectangular dark brown mark on costa at one half extending two fifths across wing; similar mark basad to postmedian fascia extending between one half and five sixths across wing; Fig. 4 – wings generally with more areas of



Figs 9-12. Male genitalia and aedeagus of *Nola* spp: (9) *N. fijiensis* Robinson; (10) *N. insularum* (Collenette); (11) *N. lichenosa* Robinson; (12) *N. transversata* Robinson.



Figs 13-16. (13) Male genitalia, aedeagus and ventral abdominal spines of *Nola savura* **sp. n.**, holotype. (14-16) Female genitalia of *Nola* spp: (14) *N. fijiensis* Robinson; (15) *N. insularum* (Colenette); (16) *N. lichenosa* Robinson.

buff shading, especially between antemedian and postmedian fasciae; markings somewhat lighter brown; the general appearance of the wings being more mottled whitish and buff than whitish and dark brown as in the other forms.

Diagnosis. The fasciae readily distinguish *N. fijiensis* from all except *N. insularum*, from which most specimens can be distinguished by their overall appearance, which is whitish with clear dark brown markings in *N. fijiensis*, while *N. insularum* has an overall buff appearance with less obvious markings. However, confusion can occur with examples similar to that shown in Fig. 4. In *N. fijiensis* the subterminal fascia is broader and darker than the postmedian fascia and three spots stand out. In *N. insularum* the reverse is the case; the postmedian fascia is darker and stands out more, taking the form of seven or eight small spots connected by fine dark lines to form a serrated line. In the male genitalia the form of the gnathos is immediately diagnostic. Also, *N. fijiensis* has no sclerotized process on either lobe of the valves, whereas *N. insularum* has a very small pointed process near the base of the ventral margin of the ventral lobe. In *N. fijiensis* the aedeagus has a single small cornutus, one fifth the length of the aedeagus, whereas in *N. insularum* the single cornutus is two fifths of its length. In the female genitalia the form of the sclerotized section of the ductus bursae is also diagnostic.

Taxonomy. The deeply divided valves and the absence of the uncus in the male genitalia confirm the placement of this species in the genus *Nola.* The position of both *N. fijiensis* and *N. insularum* has been the subject of some speculation. Holloway (1979) noted that *N. samoana* occurs in Samoa, Rotuma and New Caledonia and that it is replaced by *N. fijiensis* in Fiji. He also suggested that both species are probably derivatives of *N. insularum.* Holloway (2003) also discussed *N. pumila* Snellen, found in the Indo-Australian tropics, noting that this species is very close to *N. insularum,* which probably replaces it in the Pacific. Discussion of these relationships is outside the scope of this study, but the following points can be made: *N. fijiensis* is certainly very close to *N. insularum* and both species co-exist in Fiji. In this context it is interesting to note that the majority of *N. insularum* specimens were taken in Suva, while *N. fijiensis* was taken mainly in forest locations, suggesting that *N. insularum* might be a more recent arrival in Fiji.

***Nola insularum* (Collenette, 1928)**

Celama insularum Collenette, 1928

(Figs 5, 10, 15)

Material examined. 17 specimens: 1 from Savura, 1 from Naitasiri, 1 from Namosi, 2 from Cakaudrove and 12 from suburban Suva. Unusual among the Fijian *Nola* species with the majority being taken in suburban locations.

Redescription (Fig. 5). Head: vertex and labial palpi pale buff. Thorax: colour same as head. Wingspan 11-13 mm. Forewings: costa slightly bowed; termen

convex; apex slightly obtuse; ground colour buff or pale buff; markings brown; antemedian fascia in the form of a diffuse line from costa at one quarter to dorsum at one third, projected distad at one quarter and one half, often broken in places and obsolescent in parts; postmedian fascia from costa at three quarters to dorsum at two thirds in the form of seven or eight dots joined by well-defined narrow lines to form a serrated line; subterminal fascia from costa at four fifths to dorsum just before tornus, in the form of a narrow serrated line; a single projection distad at one quarter and two around one half somewhat darker coloured giving the impression of a series of three small pale brown spots; brown costal patch from one third to two thirds, extending one third across wing, often obsolescent or only defined by two or three brown marks on its boundary. Hind wings uniform whitish. Abdomen pale grey, suffused buff anteriorly.

Male genitalia (Fig. 10): valves deeply divided into two lobes; dorsal lobe three times the width of the ventral lobe and slightly longer; a very small pointed sclerotized process on ventral lobe approximately one third from base; uncus absent; gnathos approximately half as long as valves; narrow and parallel sided, with divided tip; aedeagus narrow, with a single straight, narrow cornutus approximately two fifths of the length of the aedeagus.

Female genitalia (Fig. 15): ductus bursae with a swollen section at approximately one third of its length, preceded by a narrow sclerotized ring; bursa copulatrix round and featureless, slightly larger than in *N. fijiensis.*

Diagnosis. The fasciae readily distinguish *N. insularum* from all except *N. fijiensis.* For the separation of these two species, see under *N. fijiensis.*

Taxonomy. The deeply divided valves and the absence of the uncus in the male genitalia confirm the placement of this species in the genus ***Nola.***

***Nola lichenosa* Robinson, 1975**

(Figs 6, 11, 16)

Material examined. 11 specimens, 1 from Savura, 2 from Namosi, 3 from Serua, 3 from Naitasiri, 1 from Tailevu and 1 from suburban Suva.

Redescription (Fig. 6). Head: vertex and labial palpi white. Thorax white with some pale buff shading. Wingspan 10-12 mm. Forewings: costa slightly bowed at base and near apex; termen convex; apex slightly obtuse; ground colour pure white; markings pale buff and black; buff patch on costa from base to one fifth; antemedial fascia consisting of a black line from costa at one quarter to dorsum at one third, broadest in median three fifths and becoming obsolete towards costa and dorsum; extending into two black subtriangular projections at one third and two thirds, mixed with some buff shading; postmedial fascia also a fine black line from costa at one half to dorsum at three fifths; strongly curved outwards below costa then sloping

back to dorsum parallel to termen; strongest at the extreme of the curvature and midway between this and dorsum; preceded by a narrow band of buff shading parallel to black line but separated from it by a narrow white strip; a black mark near costa just preceding this fascia; subterminal fascia from costa at two thirds to dorsum at three quarters, consisting of broken areas of diffuse buff shading and following roughly the line of the postmedial fascia; terminal fascia consisting of seven rectangular spots, preceded by some small areas of diffuse buff shading. Hind wings uniform white. Abdomen pure white.

Male genitalia (Fig. 11): valves very deeply divided into two lobes of almost equal width and length; ventral lobe with a double pointed sclerotized process towards the base of the ventral margin of the ventral lobe; uncus absent; gnathos approximately half as long as valves; narrow and parallel sided, with divided tip; aedeagus moderately stout with no cornuti.

Female genitalia (Fig. 16): ductus bursae with two small parallel streaks of moderate sclerotisation near base; bursa copulatrix round, much larger than the previous two species; a single large, heavily sclerotized signum in the form of a horn with pointed base, and two points at tip.

Diagnosis. In freshly emerged specimens the combination of buff and black markings is unique. In worn or pale specimens the buff marking may become obsolete but the configuration of the black markings serves to separate this species from all other Fijian *Nola* species. In the male genitalia the two lobes of the valves of equal width and the two-pointed sclerotized process are diagnostic. In the female genitalia the signum is immediately diagnostic.

Taxonomy. The deeply divided valves and the absence of the uncus in the male genitalia confirm the placement of this species in the genus *Nola.*

***Nola transversata* Robinson, 1975**

(Figs 7, 12)

Material examined. 2 specimens: 1 from Namosi and 1 from Naitasiri, both in poor condition with damaged abdomens. Robinson's type in the British Museum was examined to confirm the identification.

Note. As both the specimens in this study were missing genitalia, the male genitalia described and illustrated here are those of Robinson's type.

Redescription (Fig. 7). Head: vertex and labial palpi white. Thorax white. Wingspan 12-13 mm. Forewings: costa slightly bowed; termen convex; apex slightly obtuse; ground colour white; markings dark brown or black; small spot on costa at base; another on costa at one fifth, representing the start of the antemedian fascia; remainder of fascia almost obsolete, represented by a few faint pale brown dots; median fascia from costa at three fifths to dorsum at one half, consisting of a well-defined dark line, broadening towards costa;

postmedial fascia from costa at two thirds to dorsum at three quarters, consisting of a row of seven or eight small dots; subterminal fascia from costa at four fifths to tornus, consisting of a somewhat diffuse, serrated line, with area between this and termen more or less suffused light brown. Hind wings uniform white. Abdomen white.

Male genitalia (Fig. 12): valves deeply divided into two lobes; dorsal lobe 4-5 times the width of the ventral lobe and slightly longer; a moderately large pointed sclerotized process towards the base of the ventral margin of the ventral lobe; ventral lobe itself with hooked tip created by small pointed sclerotized process; uncus absent; gnathos approximately half as long as valves; broader at base, tapering to divided tip; aedeagus short and stout with no cornuti.

Female genitalia unknown.

Diagnosis. The dark transverse line on the forewings serves to immediately identify *N. transversata.* In the male genitalia the relative width of the two lobes of the valves is diagnostic, as is the hooked tip to the ventral lobe. The aedeagus is approximately three times as long as broad, which separates *N. transversata* from other Fijian species.

Taxonomy. The deeply divided valves and the absence of the uncus in the male genitalia confirm the placement of this species in the genus *Nola.*

***Nola savura* sp. n.**

(Figs 8, 13)

Types. Holotype ♂, FIJI, Viti Levu, Savura Creek, -18° 04′ 15″, 178° 26′ 50″, 6.iii.92, at light, J.A. Clayton. *Paratypes*: 2 ♂♂ same data as holotype, except 13.xii.91 and 13.iii.92. All deposited in the National Museums of Scotland, Edinburgh.

Description (Fig. 8). Head: vertex and labial palpi pure white. Thorax: pure white. Wingspan 13 mm. Forewings: costa bowed; termen convex; apex slightly obtuse; ground colour white; markings brown and dark brown; costal patch extending from base to one fifth, and approximately one quarter across wing; pale brown, partially outlined with dark brown shading; antemedial fascia represented by a few small brown dots, from costa just beyond basal patch to dorsum at one third; second costal patch at three fifths, dark brown; subrectangular, extending one third across wing; antemedial fascia from costa at four fifths to dorsum at three fifths and represented by a series of six brown dots in a series parallel to termen, but stopping short of costa; diffuse, narrow, brown subterminal fascia consisting of a somewhat serrated line; light brown terminal shading gradually increasing in intensity from two thirds to termen. Hind wings uniform white.

Male genitalia (Fig. 13): valves deeply divided into two lobes; dorsal lobe of roughly equal width to the ventral lobe, and slightly longer; a large, pointed

sclerotized process around the mid-point of the ventral margin of the ventral lobe; uncus absent; gnathos approximately half as long as valves; broader at base, tapering to divided tip; aedeagus five times as long as broad with no cornuti. Ventral abdominal spines widely spaced, with a broad medial emargination.

Female unknown.

Diagnosis. Nola savura is most closely related to *N. transversata*; both lack the set of forewing fasciae seen in the other species. In the male genitalia, both have a substantial sclerotised process on the ventral lobe of the valves and a relatively broad aedeagus with no cornuti. The forewing pattern, however, is immediately diagnostic. In the male genitalia the size and shape of the sclerotized process on the valves is also diagnostic. The form of the ventral abdominal spines is also distinct from other Fijian *Nola* species, as illustrated by Robinson (1975).

Taxonomy. This species is placed in the genus *Nola* based on the deeply divided valves and the absence of the uncus in the male genitalia.

Etymology. The name *savura*, a noun in apposition, refers to the location where the three specimens were taken.

Acknowledgements

I am indebted Dr Keith Bland of the National Museums of Scotland for many helpful discussions and advice and for arranging access to the entomological collections and other facilities at the Museum. Also to Dr Alberto Zilli of the British Museum for providing photographs of the genitalia slide of Meyrick's type of *Nola transversata* from which the drawing in Figure 12 was produced. I also thank the staff of the School of Science, Technology and Environment, the University of the South Pacific, Suva, Fiji, for providing access to resources and facilities at the University.

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NOSOSTICTA MOGINAE SP. N. (ODONATA: PLATYCNEMIDIDAE), A NEW DAMSELFLY FROM PAPUA NEW GUINEA

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Abstract

A new species of damselfly, *Nososticta moginae* **sp. n.** from Gulf Province, Papua New Guinea, is described from both sexes and its affinities are discussed. It represents the 80th species of the genus and is currently known only from a single location in the Kikori River Basin. A description of the hitherto unknown female of the morphologically similar *Nososticta conifera* Theischinger & Richards, 2006 is also presented.

Introduction

Since the comprehensive treatment of *Nososticta* Hagen, 1860 by Theischinger and Richards (2015a) that recognised 70 species, most of them from New Guinea, nine more species of this genus have been described by Theischinger *et al.* (2015), Theischinger and Richards (2015b, 2016) and Seehausen and Theischinger (2017).

A recent biodiversity survey in the Kikori River Basin of south-central Papua New Guinea (PNG) resulted in the collection of nine *Nososticta* species, including the poorly-known *N. conifera* Theischinger & Richards, 2006 and an unidentified species with a colour pattern similar to, but consistently different from, *N. conifera* and the recently described *N. paraconifera* Theischinger & Richards, 2016. Detailed study of morphological characters confirmed that this species differed from all congeners and we describe it here as a new species and compare it with its putative closest allies. We also describe the hitherto unknown female of *N. conifera* and illustrate both sexes of this species in life for the first time.

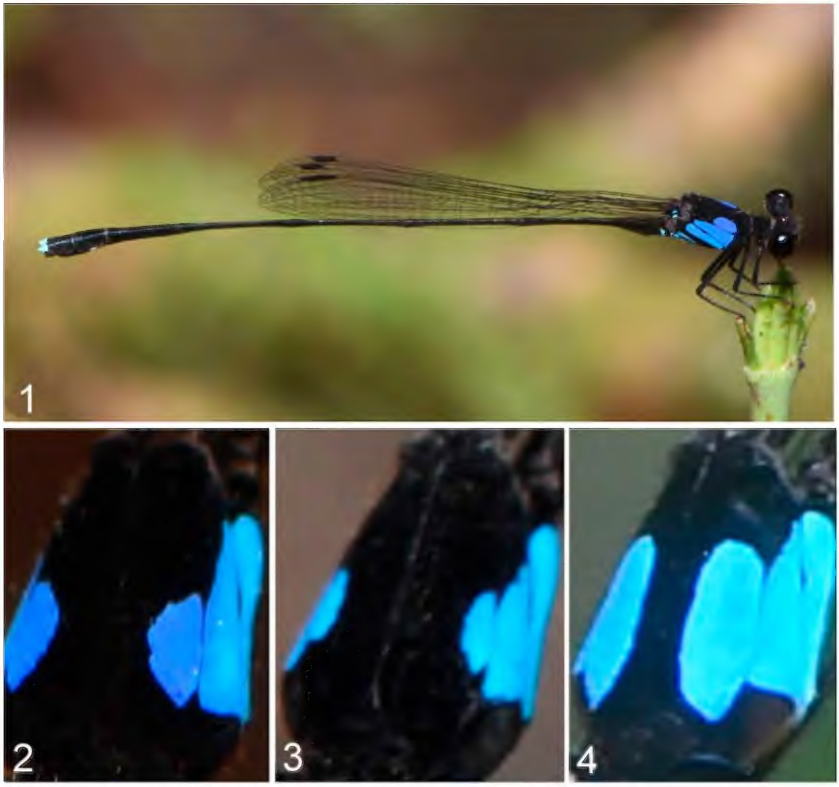
Materials and methods

Descriptive terminology largely follows Watson and O'Farrell (1991). Coloration is given as assessed from the preserved material, supplemented with photographs taken in life. Measurements are given in millimetres (mm). All illustrations were done with the aid of a camera lucida and are not to scale. Coordinates are presented using the GPS datum WGS 84. Abbreviations used are: SAMA for South Australian Museum, Adelaide, Australia; Fw for forewing; Hw for hind wing and S for segment(s).

***Nososticta moginae* sp. n.**

(Figs 1-2, 5-10)

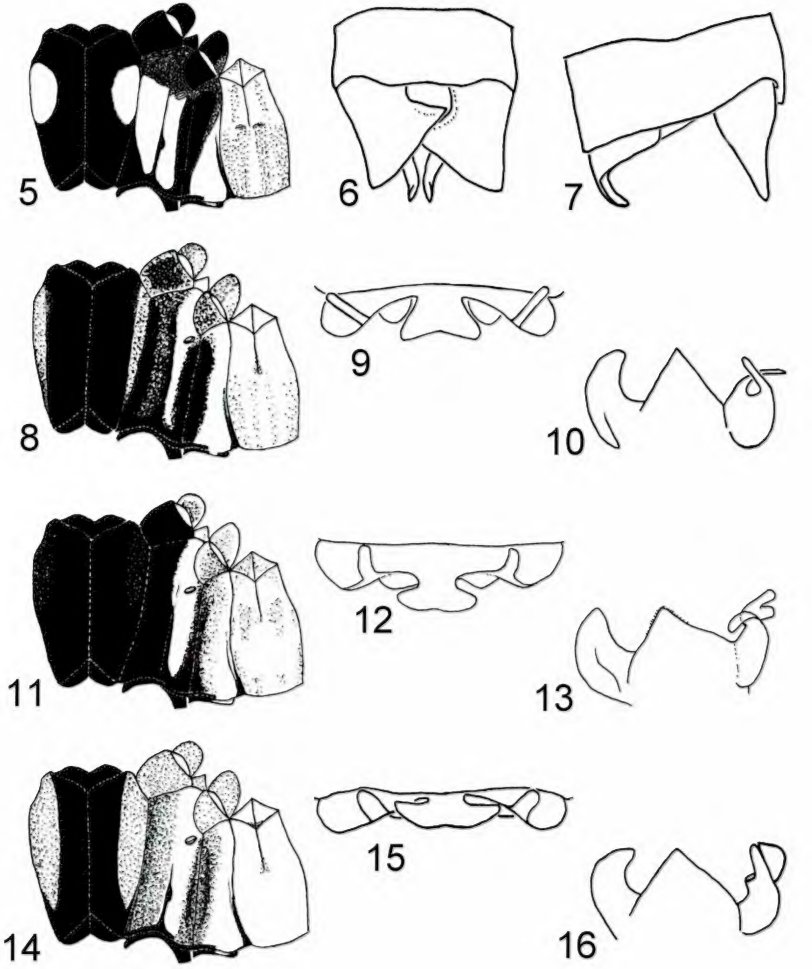
Material examined. Holotype ♂, PAPUA NEW GUINEA: Gulf Province, Wau Creek (7º7.298'S, 144º22.436'E; 20 m asl), 24-iv-2017, S.J. Richards, in South Australian Museum collection (SAMA 07-001498). *Paratypes*: 1 ♂, 1 ♀, type locality, 23-iv-2017, S.J. Richards and P.S. Toko, in South Australian Museum collection (SAMA 07-001499-1500); 1 ♂, type locality, 22-iv-2017, S.J. Richards and P.S. Toko, in South Australian Museum collection (SAMA 07-001501).



Figs 1-4. *Nososticta* spp, males: (1) *N. moginae* **sp. n.**, lateral, photographed in life at Wau Creek on 5.xii.2016 (S.J. Richards); (2-4) front of synthorax, frontal/slightly from right: (2) *N. moginae* **sp. n.**; (3) *N. paraconifera*; (4) *N. conifera*.

Diagnosis. A small *Nososticta*, the male black with largely bright blue markings mainly on synthorax including a slightly purplish tinged (in life) antehumeral patch longer than one third of length and about half as wide as the mesanepisternum. Female black and brown with long, narrow brownish

antehumeral stripe and with lateral processes of posterior lobe of pronotum thin, rather long and upright and the median element with wings pointing posterolaterad.



Figs 5-16. *Nososticta* spp: (5-10) *Nosticta moginae* **sp. n.**: (5-7) male: (5) synthorax, frontal, lateral, ventral; (6-7) anal appendages: (6) dorsal; (7) lateral; (8-10) female: (8) synthorax, frontal, lateral, ventral; (9) posterior lobe of pronotum, dorsal; (10) pronotum, lateral; (11-13) *Nososticta paraconifera*, female: (11) synthorax, frontal, lateral, ventral; (12) posterior lobe of pronotum, dorsal; (13) pronotum, lateral; (14-16) *Nososticta conifera*, female: (14) synthorax, frontal, lateral, ventral; (15) posterior lobe of pronotum, dorsal; (16) pronotum, lateral.

Description of holotype. Head: largely black; only base of labium whitish to brownish yellow. Thorax: prothorax black; median lobe of notum raised into a somewhat rugose cone on each side. Synthorax largely black; antehumeral patch blue (slight purplish tinge in life when mature), more than one third as long and approximately half as wide as mesanepisternum, connected to bright azure blue patch that extends across approximately two thirds length and almost whole width of mesepimeron and continues over approximately anterior two thirds and three quarters length of mesepisternum, only just including metathoracic spiracle; widely separated from paler blue subtriangular metepimeral patch. Metapostcoxa and anterior half of poststernum whitish to pale greyish blue, posterior half greyish to blackish brown. Legs largely black, only coxae, trochanters and base of femora slightly paler. Wing membrane hyaline, venation black; pterostigma black and a little more than twice as long as wide; overlaying slightly more than one cell to 1½ cells; postnodals 14/12; a transverse cross-vein descending from distal margin of discoidal cell to wing margin. Abdomen: S1 dorsally black, laterally black with small pale blue patch; S2 black, pale yellow adjacent to genitalia; S3-7 black, ventrally very narrowly margined greyish brown; S10 black. Anal appendages (Figs 6-7) with superiors pale blue, short and wide, rather obtuse and slightly divergent, the medioventral tooth rather broad-based, and inferiors greyish yellow to greyish brown, slim, widely and evenly curved.

Measurements: forewing 20.0 mm; hind wing 19.0 mm; abdomen plus appendages 30.5 mm.

Description of female. Head: much as in male but with very conspicuous broad and somewhat sinuous bright yellow frontal bar (from eye to eye) that also covers part of antennal base. Thorax: prothorax with most of pronotum black and sides of median lobe and pleura largely whitish blue to pale yellow; posterior lobe with large outer and small inner lateral lobe each side, the outer with rather long narrow upright process, the median element moderately long with wings pointing postero-laterad. Synthorax similar to male but largely blackish brown to brownish black instead of black; a rather indistinct paler brown narrow posteriorly tapering antehumeral stripe, no mesepimeral patch; paler blue metepisternal patch and less well-defined metepimeral patch both longer and narrower than in male. Legs with coxae and trochanters markedly paler than in male; other leg segments lost. Wings much as in male but a transverse cross-vein descending from distal margin of discoidal cell to wing margin only in hind wing. Postnodals 14/12. Abdomen: much as in male but S3-9 brownish yellow along ventral margin. Valves black, reaching backward beyond end of S10 by almost three times the length of S10, approximately 15 sharply pointed teeth along ventral margin; terebra brown and dull yellow; anal appendages dull yellowish white; supra-anal plate small, black.

Measurements. Forewing 20.0 mm; hind wing 19.0 mm; abdomen 28.0 mm.

Variation. The two male paratypes agree very well with the holotype except there are 14-16/13-14 postnodals and the blue lateral patch of abdominal S1 is slightly to markedly larger. The forewings measure 20.0 and 20.3 mm, the hind wings 18.8 and 19.3 mm and the abdomens, including anal appendages, 31.0 and 31.2 mm.

Etymology. The species is dedicated to Dr Jane Mogina in recognition of her many years working to protect the biodiversity of Papua New Guinea.

Habitat and biology

Nosoticta moginae is currently known only from the type locality, where males and females were encountered in sunny patches along small, clear and shallow (<10 cm deep) streams flowing through primary lowland forest with extensive canopy cover (Fig. 18). It shared this habitat with *N. rosea* (Ris, 1913), *N. smilodon* Theischinger & Richards, 2006 and *N. truncata* Theischinger & Richards, 2015. The species was never encountered along more open streams in the same area, where it was replaced by *N. chrismulleri* Theischinger & Richards, 2016 and *N. nigrifrons* Ris, 1913.

Figs 17-18. *Nosoticta conifer*: (17) pair in copula, photographed at a stream draining into Lake Kutubu in Southern Highlands Province, PNG (S.J. Richards); (18) habitat of *Nosoticta moginae* **sp. n.** at the type locality.

Remarks

Theischinger and Richards (2015a) established four 'species groups' to aid the classification of the speciose genus *Nosoticta. N. moginae* belongs in group D, which includes species with the front of the synthorax having patches of blue, yellow or green and the tip of the abdomen blue. Within this group *N. moginae* is most similar to *N. conifera* and *N. paraconifera*, sharing

with them simple anal appendages and a thoracic colour pattern including a blue antehumeral, mesepisternal, mesepimeral, metepisternal and metepimeral patch, with the antehumeral patch not including an area anterior to the metakatepisternum in the male (as in Fig. 5), a biconical median lobe of the pronotum in both sexes and five distinctively shaped elements in the posterior lobe of the pronotum in the female (Figs 9, 15).

The male of *N. moginae* can be readily distinguished from *N. conifera* by lacking a transverse blue frontal bar from eye to eye (versus present in *N. conifera*) and differences in the structure of the female pronotum (Figs 9, 15). Males of *N. moginae* (Figs 1-2) differ strongly from *N. paraconifera* (Fig. 3) in the markings on the synthorax, females by the presence of an antehumeral stripe (Fig. 8 *versus* Fig. 11) and in the shape of the pronotum (Figs 9-10 *versus* Figs 12-13).

Nososticta conifera Theischinger & Richards, 2006

(Figs 4, 14-17)

Material examined. 1 ♂, 1 ♀ (SAMA 07-001502-3), PAPUA NEW GUINEA: Southern Highlands Province, Tigibu Creek, Lake Kutubu (6°19.576'S, 143°15.871'E; 840 m asl), 08-v-2017, S.J. Richards leg.

Description of the female. Head: largely black, only a basal triangular patch on labium pale yellow and a very conspicuous broad and somewhat sinuous frontal bar (from eye to eye) that also covers part of the antennal base. Thorax: pronotum dorsally largely black, narrowest in median lobe, laterally largely pale to brownish yellow; posterior lobe with large outer and small inner lateral lobe, the outer with short and rather wide upright process, and median element short with wings pointing laterad; propleura bluish white and dull whitish yellow. Synthorax with mesanepisternum medially black and laterally (antehumeral stripe/patch) broadly pale brown. Most of mesokatepisternum and mesepimeron greyish brown; a narrow patch/stripe on mesepimeron adjacent to interpleural suture and most of metepisternum pale blue; a moderately wide stripe each side of metapleural suture and metakatepisternum greyish brown; most of metepimeron largely pale blue; postcoxae and poststernum very pale greyish blue. Legs with coxae pale greyish blue and brownish yellow, trochanters pale brownish yellow, basal one to two thirds of femora dull yellow, apical portion of femora and all of tibiae, tarsi and claws black. Wing membrane hyaline, venation black; postnodals 15/13; pterostigma black, about twice as long as wide, overlaying a bit less to a bit more than 1½ cells; a transverse cross-vein descending from distal margin of discoidal cell to wing margin only in one hind wing. Abdomen: largely black. S1 laterally blue; S2-9 pale to dull brownish yellow along ventral margin; S10 black. Valves black reaching backward beyond end of S10 by more than twice the length of S10, approximately 15 sharply pointed teeth along ventral margin; terebra brown; anal appendages small, dull yellowish white; supra-anal plate small, black.

Measurements: forewing 22.0 mm; hind wing 20.5 mm; abdomen 30.0 mm.

Acknowledgements

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A NOTE ON THE CORRECT REPOSITORY FOR THE HOLOTYPE OF *PSEUDAGRION FUMIPENNIS* POLHEMUS, MICHALSKI & RICHARDS (ODONATA: COENAGRIONIDAE)

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Abstract

The published repository for the holotype of *Pseudagrion fumipennis* Polhemus, Michalski & Richards, 2008, is corrected to the South Australian Museum, Adelaide, Australia, not the 'Australian Museum of Natural History, Sydney' as stated in the original description.

The coenagrionid damselfly *Pseudagrion fumipennis* Polhemus, Michalski & Richards, 2008, has a broad distribution across the lowlands and foothills of southern and eastern New Guinea (Polhemus *et al.* 2008, Kalkman and Orr 2013). It is unique among Australo-Papuan *Pseudagrion* Selys in having the tips of the wings dark brown to black (Fig. 1). In the original description, the holotype was reported to have been deposited in the 'Australian Museum of Natural History, Sydney', referring (incorrectly) to the Australian Museum, Sydney. The holotype ♂ (Papua New Guinea: Gulf Province, Sapoi River, 2 km south of Ivimka Camp, Lakekamu Basin, 146º29'45"E, 7º44'05"S, *ca* 100 m a.s.l., 29 November 1996, coll. S.J. Richards (SAMA 07-001497)) is actually deposited in the South Australian Museum, Adelaide.

Fig. 1. *Pseudagrion fumipennis* male from southern Papua New Guinea.

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NEW AUSTRALIAN RECORDS FOR *PAPILIO EUCHENOR EUCHENOR* GUÉRIN-MÉNEVILLE, 1830 AND FORM *AMBRACIA* WALLACE, 1865 OF *PAPILIO AMBRAX AMBRAX* BOISDUVAL, 1832 (LEPIDOPTERA: PAPILIONIDAE) FROM DAUAN ISLAND, TORRES STRAIT, QUEENSLAND

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Abstract

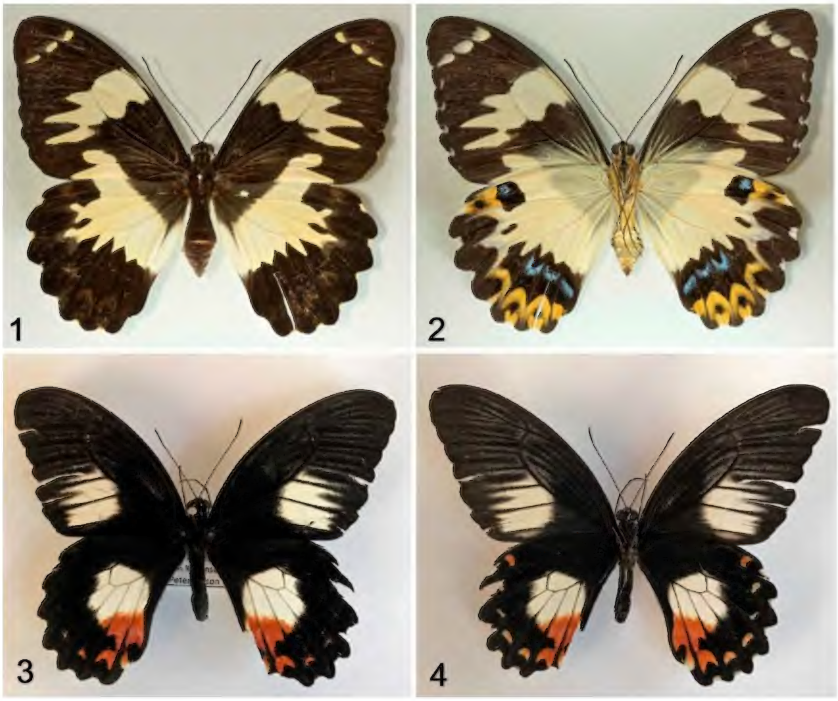
Papilio euchenor euchenor Guérin-Méneville, 1830 is recorded for the first time from Australia at Dauan Island, Torres Strait, Queensland. Form *ambracia* Wallace, 1865 of *Papilio ambrax ambrax* Boisduval, 1832, with a large median white patch on the forewing, is also recorded for the first time from Dauan Island.

Introduction

Papilio euchenor Guérin-Méneville, 1830 is restricted to the Papuan Subregion of the Australian Region, ranging from Kai, Aru, Obi, Misool, Salawati, Waigeo and the Schouten Islands of eastern Indonesia, through mainland New Guinea and various outlying islands in Papua New Guinea, to the Bismark Archipelago (Parsons 1998). Typical *P. e. euchenor* is distributed in mainland Papua New Guinea and neighbouring Manam and Umboi Islands (Parsons 1998). A very distinctive and easily recognised species, *P. e. euchenor* was first sighted in Australia by Steve and Ian Johnson on Mt Cornwallis, Dauan Island in March 2013 but not captured.

Papilio ambrax Boisduval, 1832 ranges fron Aru, Misool, Waigeo and Biak Islands of eastern Indonesia, through mainland New Guinea and various outlying islands in Papua New Guinea, to some Torres Strait islands and the east coast of Queensland from Cape Tribulation to Mackay (Parsons 1998). Typical *P. a. ambrax* occurs throughout mainland New Guinea and on the islands of Mushu, Karkar, Yule and Erub (Darnley) (Parsons 1999). Recent records of *P. a. ambrax* are from Dauan, Saibai and Mer islands in the Torres Strait (Trevor Lambkin, Steve Brown and Cliff Meyer pers. comms).

Two forms of *P. a. ambrax* females are recognised (Parsons 1998): (a) typical form *ambrax*, where the forewing has a series of greyish white streaks between the veins in the outer half and sometimes with white markings absent; and (b) form *ambracia* Wallace, 1865, with white stripes on the forewing upperside that tend to coalesce to form a medial white patch between veins 1A+2A and CuA_1. Females previously recorded from Erub (Darnley) Island in Torres Strait are mainly the typical *ambrax* form (Common and Waterhouse 1981). These original records are from Hermann Elgner's collection, now in the Australian National Insect Collection, Canberra and Museum Victoria, Melbourne. Elgner collected 16 specimens (including two females of form *ambracia*: Trevor Lambkin pers. comm.) on Erub at the turn of the 20th century.



Figs 1-4. *Papilio* spp from Dauan Island, Torres Strait: (1) *P. euchenor euchenor*, upperside; (2) ditto, underside; (3) *Papilio ambrax ambrax* form *ambracia*, upperside; (4) ditto, underside.

Results

The authors visited Dauan Island from 6-13 December 2017. The island had received good storm rain from mid-November up to the time of the visit.

A single male *P. e. euchenor* (Figs 1-2) was captured flying along the edge of scrub regrowth adjacent to a swamp area on the northern part of the island. The size and markings are typical of *P. e. euchenor*, with a wingspan of 11.2 cm, wings black with large pale yellow patches and three subapical spots on the upperside of the forewing and a large pale yellow medial patch on the upperside of the hind wing. The underside is similar to the upperside but has semicircular yellow markings extending from the margin to the submargins near the tornus and apex and some postmedial blue markings towards to dorsum and the costa. The upperside of the body is black and the underside is pale yellow.

A single female *P. a. ambrax* form *ambracia* (Figs 3-4), with a wingspan of 7.9 cm, was captured flying through the town area on Dauan Island. This specimen has the stripes on the forewing upperside tending to coalesce to

form a medial white patch between veins 1A+2A and CuA_1, typical for the form. The remainder of the markings correspond with typical form *ambrax*.

Discussion

Parsons (1998) recorded the larval food plant for *P. euchenor* as *Melicope elleryana* (F.Muell.) T.G.Hartley (formerly *Euodia elleryana*) (Rutaceae) but this plant is not known from Dauan Island. Therefore, the butterfly might be a vagrant from nearby Papua New Guinea. However, recent sightings of *P. ulysses* Linnaeus, 1758 on the island and a previous sighting of *P. euchenor,* which both feed on the same plant, suggest that a suitable larval food plant might occur.

The female *P. a. ambrax* form *ambracia* is a distinctive form closely resembling *Pachliopta polydorus* (Linnaeus, 1763) (Papilionidae: Troidini), which also occurs on the island. The female displays a non-typical flight pattern for the genus *Papilio* Linnaeus, with a more fluttering flight motion similar to that of *Pachliipta* Reakirt. Adults are generally uncommon, with four females known from Dauan Island (Trevor Lambkin pers. comm.), all of which are of form *ambracia*. Steve Brown and Cliff Meyer (pers. comms) have recorded immature stages of *P. ambrax* on citrus on nearby Saibai Island.

Acknowledgements

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NEW RECORDS OF BEE FLY (DIPTERA: BOMBYLIIDAE) AND MITE (ACARI: PYEMOTIDAE) PARASITES OF AUSTRALIAN *MEGACHILE* BEES (HYMENOPTERA: MEGACHILIDAE) IN WESTERN AUSTRALIA

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Abstract

We report three new host-parasite relationships observed during an extensive trap-nest survey of native bees in Perth, Western Australia during 2016-2017. The brood of *Megachile apicata* Smith was parasitised by a native ectoparasitic bee fly, *Anthrax incomptus* Walker and the bee offspring that developed to adulthood from the same nest being host to *Pyemotes* sp. mites. In addition, we also provide the first record of *Megachile* (*Mitchellapis*) *fabricator* Smith being host to *Anthrax incomptus.* Given that of the 691 bee tubes occupied, only seven instances of parasitism by bombyliids and one case of parasitism by *Pyemotes* involving two bee species occurred, rates of parasitism by both the fly and the mite are low, suggesting that these are not important natural enemies of native bees in the Perth metropolitan area. These new observations highlight the value of utilising bee hotels for documenting not only patterns of bee occupancy and species diversity of cavity-nesting bees, but also for discovering parasites.

Introduction

Australia has approximately 1600 described species of native bees (Hymenoptera: Apoidea), with hundreds more awaiting formal scientific description (Dollin 2016). Despite their ecological importance for pollination, there is little published information on the biology and ecology of most species. Here, we contribute to an understanding of the natural history of cavity-nesting native bees and their fly and mite parasites in southwestern Western Australia.

The Bombyliidae (bee flies) contains over 4,500 described species worldwide, with hundreds of described and undescribed species in Australia. With only one exception they are parasitoids, attacking seven different orders of insects with Hymenoptera the most commonly reported (Yeates and Greathead 1997). The majority of bombyliid species are ectoparasitoids, except for two distantly related subfamilies (Toxophorinae and Anthracinae) that are endoparasitoids (Yeates and Greathead 1997). Bombyliids are known to attack bees in the families Megachilidae, Colletidae, Apidae (*Xylocopa* Latreille) and Halictidae (Yeates and Greathead 1997).

There are approximately 250 described *Anthrax* Scopoli species globally (Evenhuis and Greathead 1999); the 14 Australian species were revised by Yeates and Lambkin (1998). *Anthrax* has been reported parasitising various species in the family Megachilidae globally but has a diverse host range, including various wasps, tiger beetles (Coleoptera: Cicindelinae) and even a lepidopteran (Yeates and Greathead 1997). *Anthrax incomptus* Walker is a common and widespread species found throughout Australia except

Tasmania and is known also from Papua New Guinea (Yeates and Lambkin 1998). In Australia it has been recorded parasitising the wasps *Sceliphron laetum* (Smith) (Sphecidae: Sphecinae), *Chrysis* sp. (Chrysididae) and *Paralastor* sp. (Vespidae: Eumeninae) (Smith 1979), as well as the megachilids *Chalicodoma* sp. (Yeates and Lambkin 1998) and *Lithurgus scabrosus* Smith (Lithurginae) (Cheesman 1936); however, the identity of the last host is suspect, given that this species is not found in Australia.

Materials and methods

Parasite-host interactions were observed coincidentally as part of a native bee survey conducted by KSP, surveying seven bushland sites and seven residential garden sites within the urbanised region of southwestern Western Australia. Eight trap-nests, using structures also known as bee hotels, were installed on tree branches at about 1.5 m height in October 2016 and were checked monthly while conducting native bee surveys. The bee hotels comprised blocks of untreated Jarrah (*Eucalyptus marginata*) of dimensions 200 mm x 100 mm x 100 mm. Fifteen cardboard bee tubes, 120 mm long, five each of 4 mm, 7 mm and 10 mm in diameter, were inserted into holes drilled in each block.

During monthly surveys at each of the sites, completed tubes (evidenced by being capped with materials characteristic for a given bee taxon) were removed and replaced with new tubes. The completed tubes were placed in individual aerated plastic containers in the laboratory to develop at room temperature and monitored every few days to record bee emergences.

Bee tubes where the occupants did not emerge prior to autumn 2017 were X-rayed with a Faxitron X-ray (10s, 24kv) in May/June and July/August to allow quantification of the number of cells and progeny and to track development without disturbance.

The adult fly parasites and *Megachile apicata* specimen with *Pyemotes* mites have been deposited in the Australian National Insect Collection, Canberra.

Results

Bombyliid parasitism

Of the 691 bee tubes that were nested in by native bees over the four months, bombyliids parasitised 7 tubes, at four of the 14 sites.

Anthrax incomptus parasite of Megachile apicata

A female *Anthrax incomptus* (Fig. 1) parasitised a 4 mm diameter bee tube collected on 20 January 2017 at Shenton Park bushland, an area of remnant *Banksia* woodland in the urbanised region of southwestern WA. The bee host was *M. apicata* Smith, identified on the basis of a female that emerged on 13 March 2017. It is likely that other bee progeny were consumed by the bombyliid, which are known to consume their hosts when in a quiescent stage (mature larva, prepupa or pupa) (Yeates and Greathead 1997).

Figs 1-2. *Anthrax incomptus* Walker from a bee tube with cells of *Megachile apicata* Smith: (1) adult female; (2) pupal exuvium.

Anthrax incomptus parasite of Megachile fabricator

A single *Anthrax incomptus* emerged from a 10 mm diameter bee tube collected on 8 February 2017 from Maniana Park, a patch of remnant bushland in the suburb of Queens Park. The fly emerged, along with four adult female *Megachile (Mitchellapsis) fabricator* Smith, between 10 and 15 March 2017. The host, *M. fabricator*, was the second most common species that utilised bee tubes in this study.

Other cases of bombyliids emerging from bee tubes

Four other bee tubes in the bee hotels were parasitised by bombyliids; however, no host bees emerged and their specific identity is unknown. It can be concluded, however, that all hosts were megachilids, based on the characteristic materials (resin, sand and mud) used to cap the completed nests. Whether the lack of host emergence was due to mortality induced by the bombyliid or other factors could not be ascertained.

An individual of *Anthrax incomptus* emerged from a 4 mm bee tube collected from Kings Park on 7 January 2017. The tube contained 11 cells, four of which had bee progeny in them, yet no bees emerged. Another 4 mm tube from the same bee hotel was collected and an X-ray revealed that it had five cells, of which only one was occupied and contained a developing bombyliid. The bombyliid failed to complete development successfully. On 4 December 2018, a male *Anthrax confluensis* Roberts emerged from a bee tube collected on 14 February 2017 at a residential garden site in the suburb of Gosnells. An X-ray of this bee tube found that it contained seven cells, three of which were occupied. From a 4 mm bee tube collected at Shenton Park on 8 February 2017, a male *Anthrax incomptus* emerged on 18 December 2017. This bee tube was found to contain five cells, two of which were occupied. Over a month later, on 28 January 2018, a male *A. incomptus* emerged from another 4 mm bee tube collected from the same bee hotel at Shenton Park on 8

February 2017. X-rays had revealed this bee tube contained two provisioned cells.

Pyemotes sp. parasitoid of Megachile apicata

The *M. apicata* specimen that emerged from the bee tube parasitised by *A. incomptus* was found to host parasitoid mites, *Pyemotes* sp. (identified by Dr Bruce Halliday, CSIRO). The mites were located on the wing bases of the mesosoma, on the femur, trochanter and coxa of the fore, mid and hind legs and on the occipital region of the head.

Pyemotes Amergling mites that parasitise bees are non-phoretic and belong to the *ventricosus* group (Houck 2012). Species in this group parasitise a range of hosts including bees, parasitising not only the adults but also larvae and pupae. Once a female mite attaches to the host it injects saliva containing neurotoxic compounds into it, leading to paralysis and eventual death (Klimov *et al*. 2016). Globally, seven species of *Pyemotes* have been described as being associated with bees (O'Connor and Klimov 2012). In Australia, five species of *Pyemotes* have been documented, of which *Pyemotes ventricosus* Newport was found on the non-Australian apid bee *Anthophora retusa* (L.) in laboratory cultures and infesting honeybee (*Apis mellifera* L.) colonies in Queensland (Halliday 2003b). Distinguishing *Pyemotes* species is very difficult (Halliday pers. comm.); none of the five species in Australia can be distinguished with confidence (Halliday 2003b). Also, the original descriptions of most species are poor (Halliday 2003b).

Discussion

With a low parasitism rate observed, it appears that parasitism of native bees by bombyliids in bee tubes is uncommon. Only one specimen was found to harbour *Pyemotes* mites, again suggesting that parasitism rates are fairly low for native bees in this region. We do not know how these rates of parasitism from tube-reared bees relates to natural parasitism rates in old cavities created by wood-boring beetles, the natural nests of the majority of megachilid species. Our data also indicate that *A. incomptus* is not a host specialist and will parasitise at least two species of megachilids that differ markedly in size: intertegular distance (the standard method for measuring bee body size: Cane 1987) of female *M. apicata* is 1.76 mm, whereas intertegular distance for female *M. fabricator* is 4.36 mm (KSP unpublished data).

All but one of the bombyliids were reared from bee tubes placed in bushland sites. This is not due to a paucity of hosts, given that trap nest occupancy did not differ between bushland and residential sites (KSP unpublished data). Our sample size is low, but it might indicate that bombyliids do not readily disperse across inhospitable 'builtspace' and/or there are insufficient nectar resources for them to conduct host searches in residential habitats.

Although it is a topic that has received only limited empirical research, parasites and parasitoids are generally known to be more vulnerable to

urbanisation than species at lower trophic levels (Fenoglio and Salvo 2010). Differential susceptibility of hosts and parasites to urbanisation might mean that, due to reduced parasitism rates, hosts might in fact achieve higher fitness in what would otherwise be 'suboptimal' habitats. Indeed, *M. fabricator* has similar nesting occupancy and emergence rates between bushland and residential sites. However, the explanation of having a refuge from parasitism in residential habitats is unlikely to explain this observation, given the single instance of parasitism. In two bee tubes where the bombyliid successfully developed, some of the host progeny still survived. This might be due to cell partitions preventing the bombyliid larva from accessing the entire brood, or other factors such as differences in timing of host and parasite development.

There have been few extensive reviews regarding the hosts of *Pyemotes* mites; however, they have been reported globally to parasitise solitary bees in the family Megachilidae (*Megachile* Latrreille and *Hoplitis* Klug), as well as diverse social genera in the family Apidae (*Apis* L., *Anthophora* Latreille, *Frieseomelitta* Ihering, *Melipona* Illiger, *Tetragonisca* Latreille) (Eickwort 1994, Vijayakumar and Jayaraj 2013, Krombein 1967, Klimov *et al*. 2016). In Australia, *Pyemotes ventricosus* has been found to parasitise the larva of the solitary, ground-nesting *Amegilla* Friese species (Apidae: Anthophorinae) (Cardale 1968). In other parts of the world *Pyemotes* have parasitised larvae in hives of honeybees and stingless bees (Melioponini), with detrimental effects for honeybee colonies (Morse and Nowogrodzki 1990). Far from a benign association, *Pyemotes tritici* (LaGrève-Fosset & Montagné) is known to kill both adults and immatures of numerous stingless bee species, leading to the complete death of the colonies (Menezes *et al*. 2009, Macías Macías and Otero Colina 2004).

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TWO NEW SPECIES OF *PALAPSALTA* (HEMIPTERA: CICADIDAE) FROM WESTERN AUSTRALIA AND NORTHERN TERRITORY

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Abstract

Two new species of the cicada genus *Palapsalta* Moulds, 2012 are described. *Palapsalta belli* **sp. n.** is a distinctive small green cicada from central Western Australia, while *Palapsalta ligneocauda* **sp. n.** is distributed throughout the Kimberley region of northern WA and the Victoria River region of the Northern Territory. A key to the eight known species of *Palapsalta* and a distribution map are provided, extending the known distribution of this genus into Western Australia.

Introduction

Moulds (2012) erected the genus *Palapsalta* Moulds to accommodate *P. eyrei* (Distant), *P. virgulata* (Ewart) and *P. vitellina* (Ewart), all of which occur in Queensland, plus *Palapsalta circumdata* (Walker), which also occurs down the north coast of New South Wales to Sydney. In their recent review of the Australian cicada genus *Pauropsalta* Goding & Froggatt, 1910 and allied genera, Owen and Moulds (2016) revised the generic diagnosis of *Palapsalta* and described two further species, namely *P. palaga* Owen & Moulds and *P. serpens* Owen & Moulds, both of which occur in the Northern Territory. In this paper, we describe two additional new species, *Palapsalta belli* **sp. n.** from central Western Australia and *P. ligneocauda* **sp. n.** from northern WA and central-western Northern Territory.

Materials and methods

Anatomical terminology follows Moulds (2005, 2012) for body structures and wing characters, Moulds (2005) for genitalia and Dugdale (1972) and Bennet-Clark (1997) for timbals. The long timbal ribs are referred to as long ribs 1 to 5, with long rib 1 being the most posterior (adjacent to timbal plate). The higher classification adopted in this paper follows Moulds (2012), revised for the genus *Palapsalta* by Owen and Moulds (2016). Measurements (in mm) are given as ranges and means (in parentheses) and include the largest and smallest specimens: head width spans across the eyes; pronotum width across the extremities of the lateral margins; abdomen width across the outer edges of the auditory capsules. Specimens were examined and photographed with an Olympus SZ61 stereo microscope and Cell-sens™ software. Photostacking of images was performed using Adobe Creative Cloud™ software.

Male genitalia were removed using a pair of surgical scissors and placed in a solution of 10% potassium hydroxide. The solution was left overnight at room temperature to clear the soft tissues and provide a clean dissection. Following clearing, the specimens were washed with ethanol and placed into a solution of either 70% ethanol or glycerol. The aedeagus was flexed posteriorly and examined under 10x magnification. Measurements were taken using a pair of Supatool™ digital calipers (DE), or an electronic digital caliper (PH), both accurate to 0.01 mm.

Abbreviations are used in the text as follows: WAM – Museum of Western Australia, Perth; AM – Australian Museum, Sydney; ANIC – Australian National Insect Collection, Canberra; DE – Private collection of Prof D. Emery, Sydney; PMH – private collection of Mr P. Hutchinson, Perth; MSM – private collection of Dr M.S. Moulds, Kuranda.

The description of calling songs follows Ewart and Marques (2008). A 'pulse' was defined as a single revolution of the timbals. The term 'syllable' was used for the smallest grouping of pulses (typically 5-10 ms duration). When multiple syllables occur in succession, without coalescence (*i.e.* where the syllables are separated by short periods of silence), this was termed a 'syllable sequence'. Where 2-9 syllables coalesce, this was referred to as a 'macrosyllable'. Bouts of calling that are dominated by macrosyllables were treated broadly as 'chirping songs'. Longer durations of continuous sound (≥10 syllables) were referred to as an 'echeme'. For a repeated unit, comprising more than one of the above terms, the term 'phrase' was adopted. A preference was generally given to recordings obtained as close as possible to the type locality.

The recording systems (RS) used were either: 1), Tascam DR-07 digital recorder with an Audio-Technica ATR-55 cardioid condenser shotgun microphone (*P. belli*); or 2), Tascam DR-40 digital recorder with Sennheiser K6/ME66 microphone (*P. ligneocauda*). Recordings were taken and provided by Dr Lindsay Popple.

Systematics

Family Cicadidae Latrielle, 1802

Subfamily Cicadettinae Buckton, 1889

Tribe Cicadettini Buckton, 1889

Genus *Palapsalta* Moulds, 2012

***Palapsalta belli* sp. n.**

(Figs 1-10)

Type material. *Holotype* ♂, Exmouth, WA, 21°55'53"S 114°06'58"E, 15.ii.2013, W. Bell (at light) (WAM). *Paratypes*: WESTERN AUSTRALIA: 3 ♂♂, 3 ♀♀, AU.WA.HOU, House Ck, ~60 km E of Nanutarra roadhouse, 22°27.970'S 116°02.240'E, 13 Feb. 2009, K. Hill, D. Marshall; 1 ♀, Exmouth, WA, 21°55'53"S 114°06'58"E, 15.ii.2015, W. Bell (at light); 1 ♂, Rocky Pool, 42 km E Carnarvon,

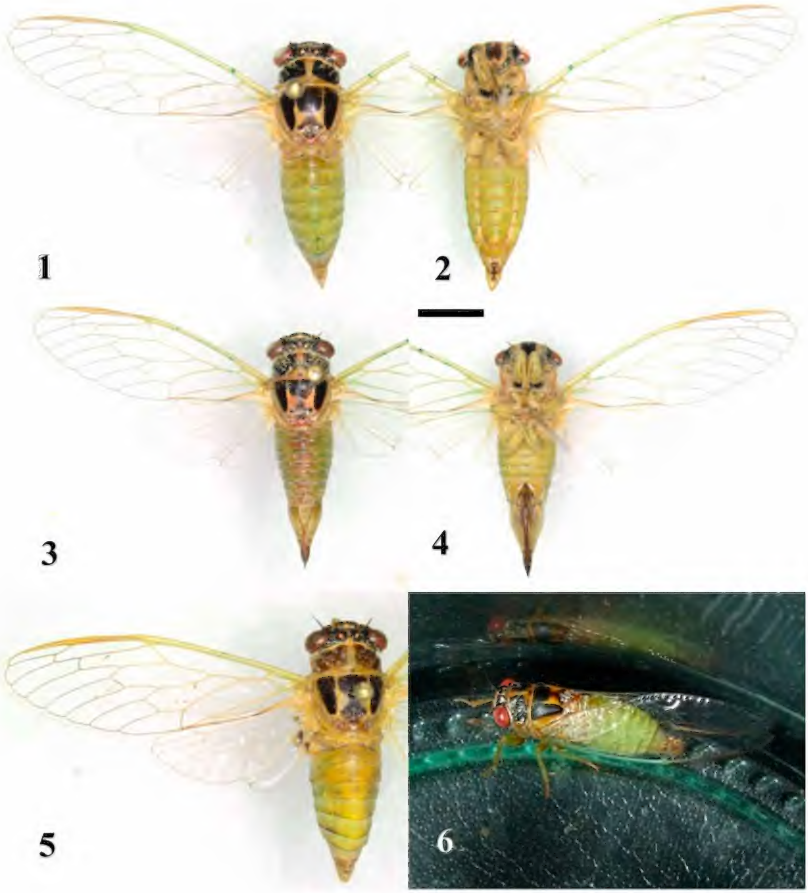
WA, 5.iii.2008, P. Hutchinson (to light) (WAM); 1 ♂, Rocky Pool, 42 km E Carnarvon, WA, 5.iii.2008, P. Hutchinson (to light) (AM); 1 ♀, Exmouth, WA, 21°55'53"S 114°06'58"E, 20.ii.2017, W. Bell (to light); 1 ♂, 57 km N Meekatharra, WA, 3.iii.2004, P. Hutchinson; 1 ♂, Ashburton River, Nanutarra, WA, 7.iii.2004, P. Hutchinson (150W MV light); 1 ♀, Gascoyne River, South Branch, 146 km N Meekatharra, WA, 12.iii.2011, P. Hutchinson (to light); 4 ♂♂, Rocky Pool, 42 km E Carnarvon, WA, 5.iii.2008, P. Hutchinson (to light) (DE); 1 ♂, Cathedral Gorge, 18 km NW Newman, WA, 23°14'47"S 119°35'16"E, 5.iii.2004, P. Hutchinson (to light); 9 ♂♂, Rocky Pool, 42 km E Carnarvon, WA, 5.iii.2008, P. Hutchinson (to light); 2 ♀♀, Gascoyne River, South Branch, 146 km N Meekatharra, WA, 12.iii.2011, P. Hutchinson (ULP lamp) (PMH); 3 ♂♂, 1 ♀ (1 ♂ genitalia preparation PAL 1), Rocky Pool, 42 km E. Carnarvon, 5 Mar. 2008, P. Hutchinson; 1 ♂, Ashburton River, Nanutarra, 7 Mar. 2004, P. Hutchinson; 1 ♀, Minilya Rdhse, 10 Mar. 2004, P. Hutchinson; 3 ♂♂, 3 ♀♀ (1 ♂ genitalia preparation PAL 11), AU.WA.HOU, House Ck, ~60 km E of Nanutarra roadhouse, 22 27.970'S 116 02.240'E, 13 Feb. 2009, K. Hill, D. Marshall (MSM).

Description of Holotype male (Figs 1-2, 6-10). Head slightly wider than lateral margins of pronotal collar but narrower than lateral angles; black with ochraceous triangular spot at posterior midline, ocelli orange-yellow. Eyes crimson when live, brown on dried specimens. Postclypeus ochraceous above with broad black fascia on posterior midline, ventral surface ochraceous, transverse ridges black, lorum black, ochraceous anteriorly, gena black. Anteclypeus greenish centrally, becoming blacker laterally. Rostrum ochraceous tending black distally, extending to the middle of the mid coxae. Antennomeres brown to black, sometimes tending orange distally. Supra-antennal plates ochraceous, becoming black towards eyes.

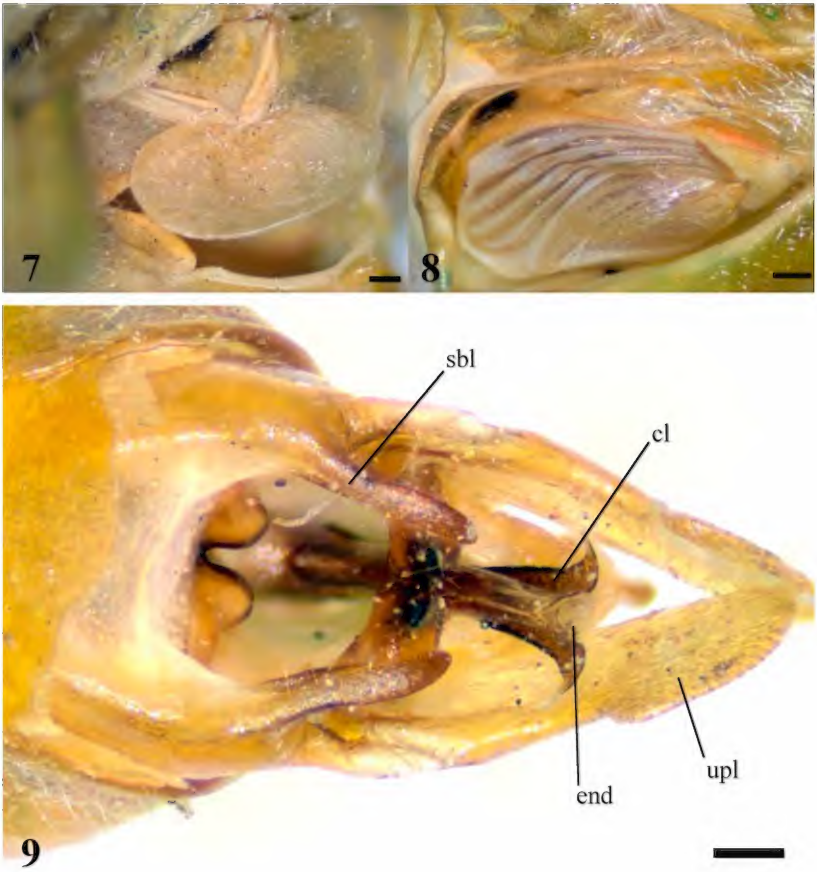
Thorax. Pronotum light brown to black with ochraceous markings; anterior margin ochraceous; vitta along midline ochraceous yellow, extending from head to pronotal collar, widest near head and pronotal collar; a black to light brown spot on midline adjacent to pronotal collar; pronotal collar ochraceous yellow with lateral margin clearly ampliate. Mesonotum ochraceous with black markings; lateral and submedian sigilla black, black between anterior arms of cruciform elevation, tending brown to black anteriorly, scutal depressions pale brown; cruciform elevation pale orange-brown. Metanotum ochraceous light green. Legs ochraceous green, basisterna 2 black. Femora with spines brown, becoming black at tips; tibiae ochraceous; pretarsal claws pale brown, black at tips. Meracanthus pale green, triangular, pointed posteriorly, marginally overlapping opercula. Wings hyaline. Forewings with fused stem of veins M and CuA completely fused before meeting basal cell; costal veins green yellow tending brown distally, other veins green, tending lighter posteriorly; basal cells translucent, basal membranes very pale orange. Hind wings with 6 apical cells; venation greenish; plagas muddy grey. Opercula yellow cream, rounded centrally, spatulate, almost reaching distal margin of tympanal cavity; widely separated; slightly darker colour on a low rounded swelling of epimeron 3 (Fig. 7). Timbals grey, with four long, brown

ribs across the width of timbal membrane, long rib 5 discontinuous, spanning the middle two-thirds of the timbal cavity, timbal plate light brown, bifurcating over lateral third (Fig. 8).

Abdomen diamond-shaped in cross section with epipleurites flexed inwards from junction with tergites. Tergites 1-7 green, tending lighter along posterior margins; tergite 8 yellow-brown posteriorly, straw coloured laterally, dorsal beak ochraceous. Sternites I and II green, darker along midline, sternites III-VII green, yellow posterior margins, sternite VIII ochraceous, with silvery pubescence.



Figs 1-6. *Palopsalta belli* **sp. n.**: (1) holotype male (Exmouth, WA, 21°55'53"S 114°06'58"E), dorsal habitus; (2) male, ventral habitus; (3) female (Exmouth WA), dorsal habitus; (4) female, ventral habitus; (5) male (Rocky Pool, inland WA), dorsal habitus; (6) live holotype male from Exmouth (photo by W. Bell). Scale bar = 4 mm.



Figs 7-9. *Palapsalta belli* **sp. n.**: (7) photostack of male left opercula, with anterior margin at top and dorsal margin at right; (8) photostack of male left timbal, with anterior margin at top and dorsal margin at right; (9) photostack of the terminal endotheca of male with tergite 8 removed, viewed ventrally. Specimen from Exmouth (21°55'53"S 114°06'58"E). Scale bars = 0.2 mm; characters as described in Fig. 10.

Genitalia (Figs 9-10). Upper pygofer lobes large, yellow brown; in lateral view slightly longer than wide, posteriorly asymmetrically dilated, rounded ventrally, more concave along the margin approaching the basal lobe; in ventral view, angled medially. Basal pygofer lobes undeveloped, flap-like. Secondary basal lobes spine-like, in lateral view clearly projecting and subtriangular, in ventral view flattened laterally and finger-like, slightly projecting laterally. Anal styles pinkish red. Median lobe of uncus wider than long with a rounded apex, duck-bill shape. Claspers claw-like, of medium width in dorsal view, apices tapered laterally and curved outwards. Aedeagus

with pseudoparameres of similar length to theca, above theca in lateral view, in dorsal view parallel to each other, not curved. Theca nearly straight, parallel sided, circular in cross-section, sloping ventrally around 30° towards apex; apex convex, semicircular, with 'saw-like teeth' around the dorsal circumference, 2-3 rows of small cornuti over remaining ventral surface; in dorsal view, apex appears like the open flower of a lily or pitcher plant, with apex directed craniad (Fig. 10).

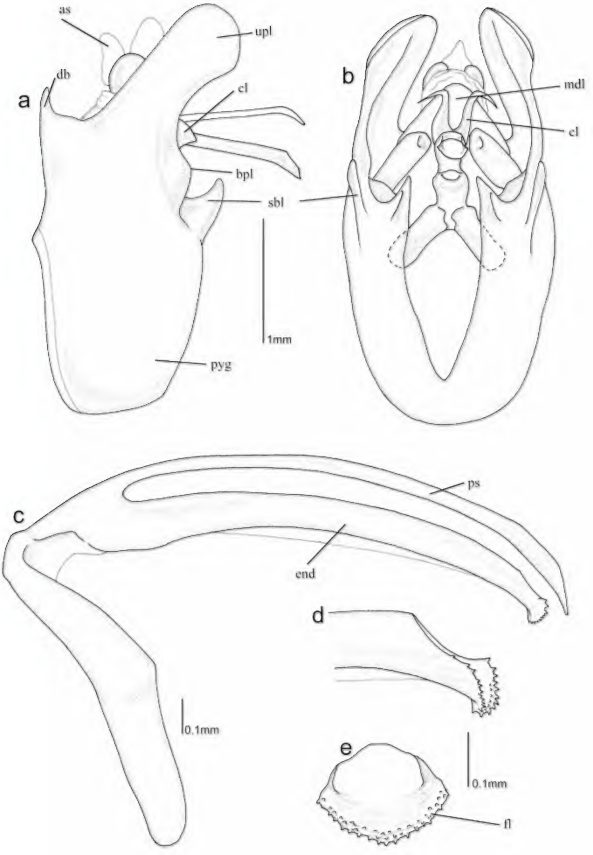


Fig. 10. *Palapsalta belli* **sp. n.**, illustration of male pygofer and internal genitalia: (a), viewed laterally from the left; (b), viewed ventrally; (c), aedeagus; (d), apex of theca, viewed laterally; (e), apex of theca, viewed ventrally. Characters include: as, anal styles; bpl, basal lobe of pygofer; cl, clasper; db, dorsal beak; end, endotheca; fl, lateral flanges of thecal apex; mdl, medial lobe of uncus; ps, pseudoparamere; pyg, pygofer, sbl, secondary basal lobe of pygofer; upl, upper lobe of pygofer. Specimen from Exmouth (21°55'53"S 114°06'58"E).

Female (Figs 3-4). Head and thorax similar to male, with ochraceous markings on pronotum, pronotal collar and mesonotum tending burnt orange, cruciform elevation orange-brown. Abdomen similar to male. Tergites with brown-orange markings along midline, abdominal segment 9 orange-brown anteriorly and along dorsal midline, with a greenish subdorsal fascia on each side of midline, dorsal beak orange-brown. Ovipositor sheath long, dark brown to black, extending 1.0-1.5 mm beyond posterior abdomen; ovipositor dark brown, black at tip.

Measurements. Range and mean (in mm) for 19 ♂♂, 6 ♀♀; includes smallest and largest of available specimens. Length of body: male, 14.7-16.6 (15.7); female, 16.5-17.6 (17.1). Length of forewing: male, 17.3-19.9 (18.4); female, 17.6-21.7 (19.5). Width of forewing: male, 5.4-6.4 (6.1); female, 6.0-6.9 (6.6). Width of head (including eyes): male, 4.2-5.3 (4.8); female, 4.8-6.0 (5.4). Width of pronotum (across lateral angles): male, 4.1-5.1 (4.5); female, 4.6-5.5 (5.1). Abdominal width (across segment II): male, 3.9-4.7 (4.5); female, 3.8-4.6 (4.4). Ovipositor length: 5.7-6.2 (6.0).

Variation. In some inland specimens, scutal depressions are encompassed in black fascia extending anterior from cruciform elevation (Fig. 5). In collections, the greenish coloration fades to yellow-brown unless specimens have been preserved by the inoculation, when fresh, of around 50 µl of 2% buffered formalin.

Distinguishing features. The light green ochraceous coloration of *P. belli* sp. n. clearly differentiates this species from all other described species in genus *Palapsalta,* which range from brown-cream (*P. serpens*) to brown-black and orange (*P. circumdata, P. eyrei, P. palaga, P. virgulata* and *P. vitellina*). The male genitalia are also unique, with the endotheca terminating with convex 'floral-type' opening lined dorsally with saw-like teeth. The ovipositor of the females extends <1.5 mm beyond abdominal segment 9, comparable with those of *P. eyrei, P. virgulata* and *P. vitellina,* while ovipositors of *P. palaga, P. serpens* and *P. circumdata* extend >1.5 mm.

Etymology. This species is named after William Bell, who captured several specimens at Exmouth over many years.

Distribution, habitat and behaviour. Known from around the Pilbara and Gascoyne regions in Western Australia (Fig. 23). Specimens collected in Exmouth arrived at light between 0100-0300h, while those collected at light by PMH in other locations arrived between 1900-0100h.

The male calling song consists of two components (Fig. 11). The first is a short series of long buzzes that gradually crescendo and lasts between 850 and 1250 milliseconds (ms) duration (n = 2). Each buzz is separated by a period of silence between 450 and 800 ms duration. The second component is a long lilting series comprising between 32 and 68 macrosyllables (n = 3).

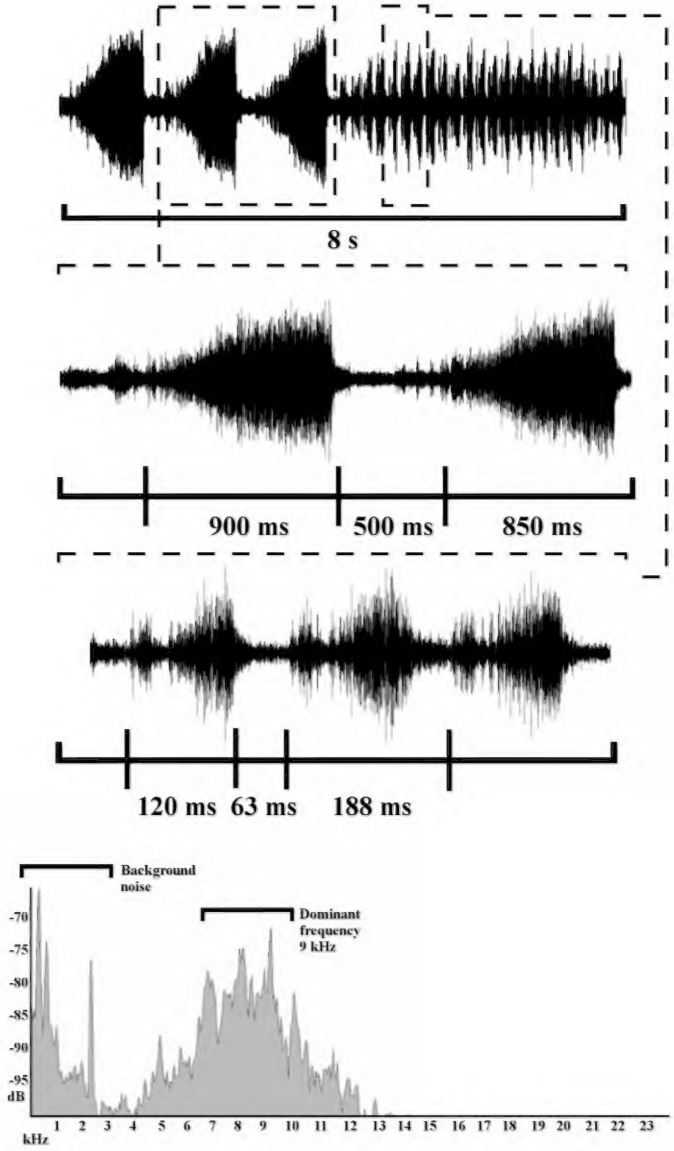


Fig. 11. Male calling song structures of *Palapsalta belli* **sp. n.**, illustrated in waveform plot form. Each lower plot is expanded from the one above, to illustrate the finer temporal structure of each song comparison. The spectrogram at the bottom of the figure displays song frequency. Recordings are from South Gascoyne River (25°36'S 119°14'E) by Dr L. Popple.

Each macrosyllable ranges between 120 and 188 ms duration and is separated by a brief period of silence ranging between 54 and 72 ms duration (n = 3). Males tend to call from the upper branches of *Acacia* species in open woodland (Figs 24-25). Populations are generally small with erratic emergences. Specimens have been collected at light from November to March, mainly within a week after rains on humid nights.

***Palapsalta ligneocauda* sp. n.**

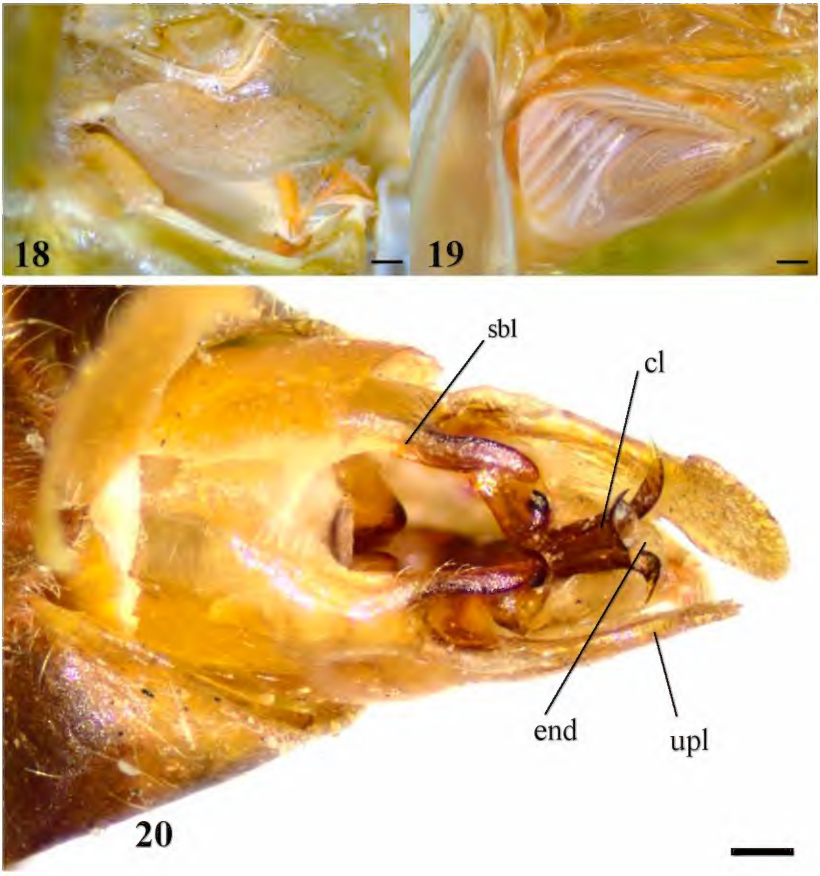
(Figs 12-21)

Type material. *Holotype* ♂, AU.WA.NCH, nr Nicholson R., 145 km E of Halls Creek, 18°08.41'S 128°42.003'E, 23 Jan. 2010, K. Hill & D. Marshall (WAM). *Paratypes*: WESTERN AUSTRALIA: 4 ♂♂, 5 ♀♀, AU.WA.NCH, nr Nicholson R., 145 km E of Halls Creek, 18°08.41'S 128°42.003'E, 23 Jan. 2010, K. Hill & D. Marshall; 2 ♂♂, 2 ♀♀, AU.WA.WAL, Walardi Campground in Purnululu NP, (Bungle Bungle Rg), 258 m, 17°31.279'S 128°18.172'E, 26 Nov. 2011, K. Hill, D. Marshall; 5 ♂♂, 3 ♀♀, (1 ♂ genitalia preparation) AU.WA.PCC, ~57 km E of Great Northern Hwy on Parry Ck Rd, SE of Wyndham, 15°59.194'S 128°40.138'E, 32 m, 28 Nov. 2011, K. Hill, D. Marshall; 5 ♂♂, 2 ♀♀, AU.WA.GEI, Geike Gorge, 21 km NE of Fitzroy Crossing, 130 m, 18°06.377'S 125°42.036'E, 24 Nov. 2011 K. Hill, D. Marshall; 5 ♂♂, 5 ♀♀, AU.WA.MRY, Mary R., 109 km W of Halls Creek, 18°43.622'S 126°52.210'E, 286 m, 24 Jan. 2010, K. Hill, D. Marshall (WAM); 6 ♂♂ (1 genitalia preparation PAU 96), Tunnel Creek, E of Derby, 1 Nov. 1978, M.S. & B.J. Moulds; 5 ♂♂, 5 ♀♀ (1 ♂ genitalia preparation PAL 12), AU.WA.NCH, nr Nicholson R., 145 km E of Halls Creek, 18°08.41'S 128°42.003'E, 23 Jan. 2010, K. Hill & D. Marshall; 2 ♂♂, 2 ♀♀ (1 ♂ genitalia preparation PAL 4), AU.WA.WAL, Walardi Campground in Purnululu NP, (Bungle Bungle Rg), 258 m, 17°31.279'S 128°18.172'E, 26 Nov. 2011, K. Hill, D. Marshall; 5 ♂♂, 3 ♀♀ (1 ♂ genitalia preparation PAL 3), AU.WA.PCC, ~57 km E of Great Northern Hwy on Parry Ck Rd, SE of Wyndham, 15°59.194'S 128°40.138'E, 32 m, 28 Nov. 2011, K. Hill, D. Marshall; 5 ♂♂, 2 ♀♀ (1 ♂ genitalia preparation PAL 6), AU.WA.GEI, Geike Gorge, 21 km NE of Fitzroy Crossing, 130 m, 18°06.377'S 125 42°036'E, 24 Nov. 2011 K. Hill, D. Marshall; 5 ♂♂, 5 ♀♀ (1 ♂ genitalia preparation PAL 7), AU.WA.MRY, Mary R., 109 km W of Halls Creek, 18°43.622'S 126°52.210'E, 286 m, 24 Jan. 2010, K. Hill, D. Marshall; 4 ♂♂, 5 ♀♀, Kununurra, 28 Jan. 1987, E.A. Henty (MSM). NORTHERN TERRITORY: 8 ♂♂, 14 km NW Cape Crawford, 18°43'S 135°41E, 6 Nov.1975 (ANIC; 5684-6 [3 only]); 10 ♂♂, 10 ♀♀, (1 ♂ genitalia preparation PAU 105), Victoria R., 18 km W of Timber Creek township, 25 Dec. 1991, M.S. & B.J. Moulds (MSM).

Description of Holotype male (Figs 12-13, 18-21). Head slightly wider than lateral margins of pronotal collar but narrower than lateral angles; dark brown to black centrally, brown towards eyes, with ochraceous triangular spot at posterior midline, ocelli red. Eyes reddish brown on dried specimens. Postclypeus ochraceous above with broad black fascia on posterior midline, ventral surface green ochraceous, green to orange along midline, transverse ridges green, lorum light brown, ochraceous anteriorly. Anteclypeus greenish centrally, becoming darker laterally. Rostrum green anteriorly, becoming ochraceous, black distally, extending to the middle of the mid coxae. Supra-antennal plates ochraceous.

Thorax. Pronotum brown with ochraceous markings; anterior margin light green to ochraceous; vitta along midline ochraceous yellow, extending from head to pronotal collar, widest near head and expanded along pronotal collar; pronotal collar light green ochraceous with lateral margin clearly ampliate. Mesonotum light brown with ochraceous markings; lateral and submedian sigilla darker brown, greenish brown between anterior arms of cruciform elevation, scutal depressions pale brown; cruciform elevation orange-red, lighter towards extremities. Metanotum ochraceous to light brown.

Figs 12-17. *Palapsalta ligneocauda* **sp. n.**: (12) holotype male (nr Nicholson River, WA, 18°08'41"S 128°42'00"E), dorsal habitus; (13) male, ventral habitus; (14) female (Halls Creek, WA, 18°42'62"S 126°52'21"E), dorsal habitus; (15) female, ventral habitus; (16) male (brown variant, Nicholson R., WA), dorsal habitus; (17) female, (brown variant), dorsal habitus. Scale bar = 2 mm.



Figs 18-20. *Palapsalta ligneocauda* **sp. n.**: (18) photostack of male left opercula, with anterior margin at top and dorsal margin at right; (19) photostack of male left timbal, with anterior margin at top and dorsal margin at right; (20) photostack of the terminal endotheca of male with tergite 8 removed, viewed ventrally. (18-19) specimen from Mary River, WA (18°43'62"S 126°52'21"E); (20) specimen from Tunnel Ck, nr Derby, WA. Scale bars = 0.2 mm; characters as described in Fig. 21.

Legs ochraceous green. Femora with spines brown, becoming black at tips; tibiae ochraceous; pretarsal claws pale brown, black at tips. Meracanthus pale green, triangular, pointed posteriorly, marginally overlapping opercula. Wings hyaline. Forewings with fused stem of veins M and CuA completely fused before meeting basal cell; costal vein yellow tending brown distally, other veins green, tending lighter posteriorly; basal cells translucent, basal membranes pale orange. Hind wings with 6 apical cells; venation greenish; plagas pale brown. Opercula yellow-cream, rounded centrally, spatulate,

almost reaching distal margin of tympanal cavity; widely separated (Fig. 18). Timbals grey, with four long, grey-brown ribs across the width of timbal membrane, long rib 5 discontinuous laterally, timbal plate light brown, bifurcating over lateral third (Fig. 19).

Abdomen triangular in cross section with epipleurites flexed inwards from junction with tergites. Tergites 1-7 light green centrally, tending lighter laterally and along posterior margins; tergite 8 dark brown to black, lighter posteriorly, dorsal beak light brown. Sternites I-VI green, darker along midline, sternite VII dark brown to black with lighter lateral margins, sternite VIII light brown ochraceous, with silvery pubescence.

Genitalia (Figs 20-21). Upper pygofer lobe large, yellow-brown; in lateral view slightly longer than wide, posteriorly asymmetrically dilated, distinctly hooked and rounded ventrally, more concave along the margin approaching the basal lobe; in ventral view, angled medially. Basal pygofer lobe undeveloped, flap-like. Secondary basal lobe undeveloped. Anal styles pinkish red. Claspers claw-like, apices broadly tapered laterally and curved outwards. Aedeagus with pseudoparameres same length as theca, above theca in lateral view, in dorsal view parallel to each other, curved at tips (Fig. 21). Theca nearly straight, parallel sided, circular in cross-section, angled ventrally around 30° towards apex; apex convex, semicircular, with 'saw-like teeth' around the dorsal circumference, several small cornuti around midline; in dorsal view, apex appears flower-like with apex directed craniad (Fig. 20).

Female (Figs 14-15). Head and thorax similar to male, with lighter ochraceous markings on pronotum, pronotal collar and mesonotum tending burnt orange, cruciform elevation orange-brown. Abdomen similar to male. Tergites with brown-orange coloration along midline; sternites yellow tending green laterally; abdominal segment 9 darker green laterally, a light orange stripe along the dorsal midline, dorsal beak orange-brown. Ovipositor sheath long, dark green to brown, extending <1.0 mm beyond apex of abdominal segment 9; ovipositor dark brown, black at tip.

Measurements. Range and mean (in mm) for 15 ♂♂, 4 ♀♀; includes smallest and largest of available specimens. Length of body: male, 11.4-14.7 (13.1); female, 13.5-14.7 (16.2). Length of forewing: male, 13.6-17.8 (16.0); female, 15.6-17.0 (16.2). Width of forewing: male, 4.4-6.0 (5.3); female, 5.2-5.8 (5.6). Width of head (including eyes): male, 3.8-5.1 (4.4); female, 4.5-5.0 (4.8). Width of pronotum (across lateral angles): male, 3.0-4.2 (3.7); female, 4.2-4.6 (4.4). Abdominal width (across segment II): male, 2.9-4.2 (3.8); female, 3.6-3.8 (3.7). Ovipositor length: 5.1-5.6 (5.3).

Variation. A small percentage of specimens present with more orange-brown coloration, rather than green (Figs.16-17). The head is dark brown to black between the eyes, with lateral margins of the anteclypeus, gena and lorum dark brown to black.

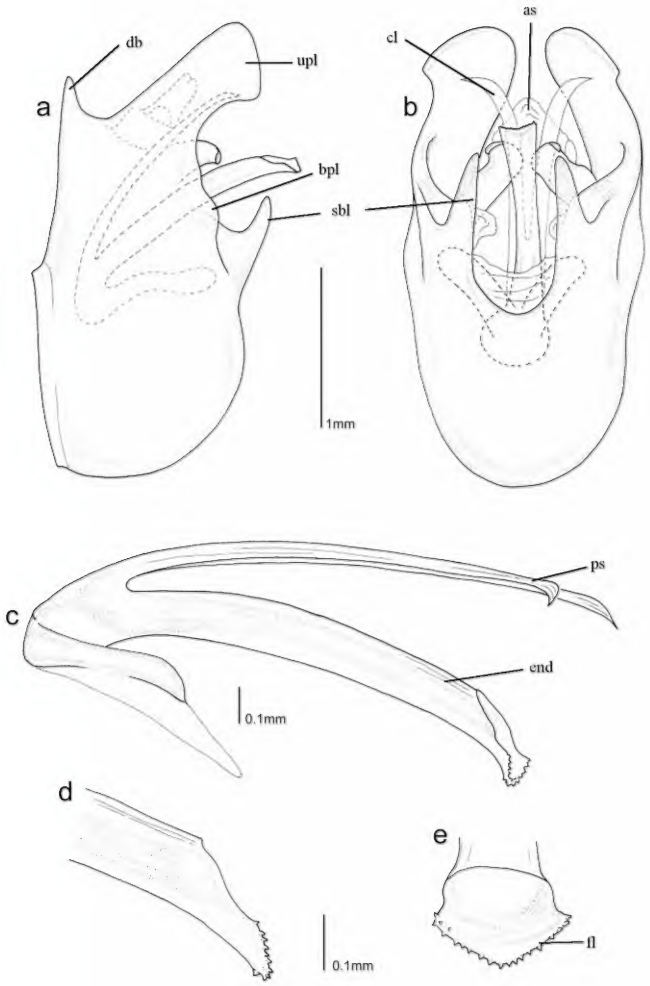


Fig. 21. *Palapsalta ligneocauda* **sp. n.**, illustration of male pygofer and internal genitalia: (a), viewed laterally from the left; (b), viewed ventrally; (c), aedeagus; (d), apex of theca, viewed laterally; and, (e), apex of theca, viewed ventrally. Characters include: as, anal styles; bpl, basal lobe of pygofer; cl, clasper; db, dorsal beak; end, endotheca; fl, lateral flanges of thecal apex; ps, pseudoparamere; sbl, secondary basal lobe of pygofer; upl, upper lobe of pygofer. Specimen from Geike Gorge, WA (15°59'19"S 128°40'14"E).

Distinguishing features. The light green ochraceous coloration of *P. belli* sp. n. and *P. ligneocauda* sp. n. clearly differentiate these two species from all other members of genus *Palapsalta,* which range from brown-cream (*P. serpens*) to brown-black and orange (*P. circumdata, P. eyrei*, *P. palaga*, *P. virgulata* and *P. vitellina*). The male genitalia are also unique, with the endotheca terminating with convex 'floral-type' opening lined dorsally with saw-like teeth. The ovipositor of the females of both *P. belli* sp. n. and *P. ligneocauda* sp. n. extend <1.5 mm beyond abdominal segment 9, comparable with those of *P. eyrei*, *P. virgulata* and *P. vitellina*, while ovipositors of *P. palaga, P. serpens* and *P. circumdata* extend >1.5 mm.

Palapsalta ligneocauda sp. n. can be readily distinguished from specimens of *P. belli* sp. n. by the distinctive wood-brown coloration of tergite 8 on the former. In addition, the prominent black markings on the ventral postclypeus, pronotum, basisterna 2 and submedian and lateral sigilla of *P. belli* sp. n. are dark brown to ochraceous on *P. ligneocauda* sp. n. In addition, the genitalia of *P. belli* sp. n. and *P. ligneocauda* sp. n. differ in the following aspects: (1), the ventral angle of the upper pygofer lobe is hooked on *P. ligneocauda* sp. n. and rounded on *P. belli* sp. n.; (2), the secondary basal lobe is undeveloped on *P. ligneocauda* sp. n.; (3), the prominent rows of subapical cornuti on the terminal endotheca of *P. belli* sp. n. are absent on *P. ligneocauda* sp. n.

Specimens of *P. ligneocauda* sp. n. superficially resemble *Taurella forresti* (Distant) but, under closer examination, the former are distinguished by genus-specific characters of 5 timbal ribs and terminally rounded opercula (Moulds 2012).

Etymology. The characteristic dark, wood-brown coloration of tergite 8 and sternite VIII gives this species its name.

Distribution, habitat and behaviour. Known from around the northern Kimberley regions in Western Australia across to the Victoria River region of western Northern Territory (Fig. 23). Considering the biogeography for this species, the location data for the 3 specimens of *P. ligneocauda* sp. n. remaining in ANIC, from the 8 recorded from Cape Crawford, NT, are considered unreliable.

The male calling song consists of two components (Fig. 22). The first is a series of short buzzing notes that crescendo between 280 and 400 ms duration (n = 3). The second component is a long lilting series that can range between 1 and 5.5 seconds duration (n = 4). The lilting component comprises a repeating series of a short macrosyllable (between 23 and 43 ms duration; n = 4), followed by an echeme (between 90 and 110 ms duration). Males have been known to call from the upper branches of eucalypts in open woodland (akin to Fig. 24). Specimens have been collected from November to March, and can be particularly abundant immediately after rains.

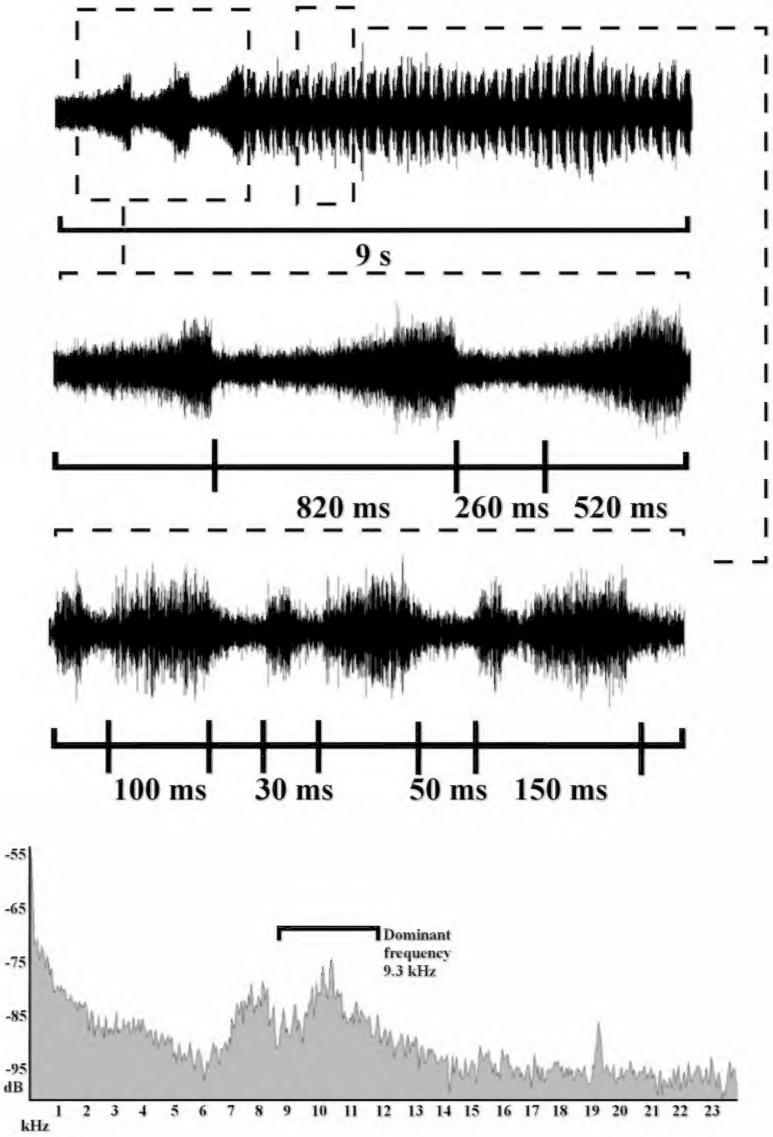
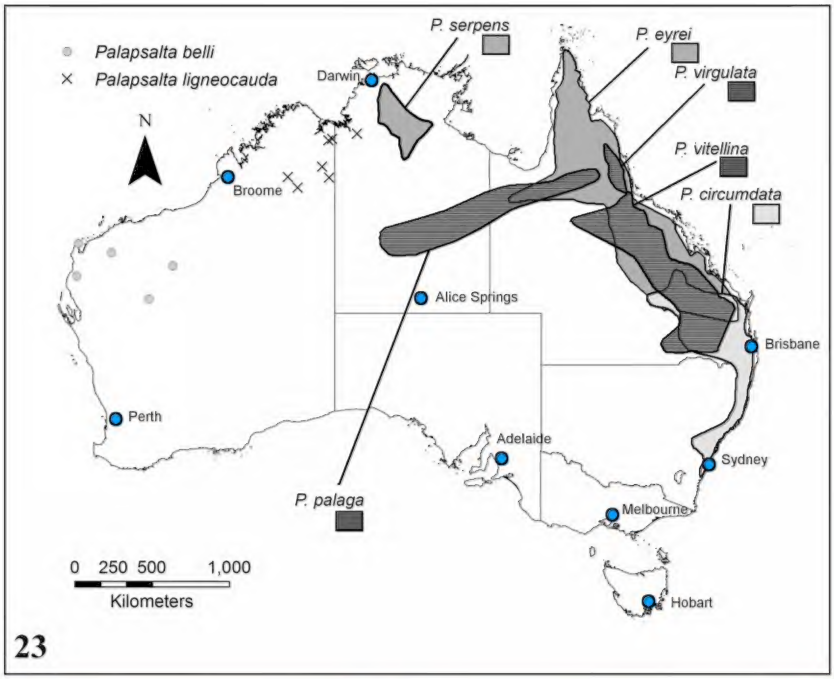


Fig. 22. Male calling song structures of *Palapsalta ligneocauda* **sp. n.**, illustrated in waveform plot form. Each lower plot is expanded from the one above, to illustrate the finer temporal structure of each song comparison. The spectrogram at the bottom of the figure displays song frequency. Recordings are from Purnululu (17°31'S 128°18'E) and Victoria River (15°37'S 131°08'E) by Dr L. Popple.



Figs 23-25. (23) Distribution map of Australia, showing current locations for species of *Palapsalta* Moulds; (24) Gascoyne River (south branch) at great northern highway, 146 km north of Meekatharra, W.A. Typical habitat of *Palapsalta belli* **sp. n**. and *P. ligneocauda* **sp. n.** (photo by PMH); (25) Coastal plain, Northwest Cape, *ca* 2 km SE Exmouth, W.A. Typical habitat of *Palapsalta belli* **sp. n.** (photo by PMH).

Key to *Palapsalta* species (modified from Owen and Moulds 2016)

1 Anterior lateral margins of at least some tergites coloured orange or green ……..... 2

– Anterior lateral margins of tergites coloured black with large white or pale brown spot on lateral abdomen covering tergites 3-5 ..... *P. serpens*

2 Black markings along midline of tergites 3

– Orange or orange-brown markings along midline of tergites, or tergites unicolorous green or brown 5

3 Black markings along midline of tergites, wider around midline, thinning laterally 4

– Black markings on tergites about the same width on midline and laterally ..... *P. circumdata*

4 Male opercula coloured sandy brown to yellow-brown; female ovipositor sheath extending 1-2 mm beyond abdominal segment 9 ..... *P. vitellina*

– Male opercula coloured dark brown to black anteriorly; female ovipositor extending < 0.5 mm beyond abdominal segment 9 ..... *P. virgulata*

5 Orange or orange-brown markings along midline of tergites 6

– Midline of tergites green (same as base colour) 8

6 Tergites 1 and 2 orange ..... *P. eyrei*

– Tergites 1 and 2 brown, sometimes tending black 7

7 Pronotum black with yellow markings ..... *P. palaga*

– Pronotum brown with ochraceous markings ..... *P. ligneocauda* **sp. n.** (brown form)

8 Tergite 8 yellow-brown; ventral surface of postclypeus and pronotum black ..... *P. belli* **sp. n.**

– Tergite 8 dark brown to black; ventral surface of postclypeus and pronotum brown to ochraceous ..... *P. ligneocauda* **sp. n.**

Acknowledgements

The authors are sincerely grateful to Dr Max Moulds for access to specimens and their data from his extensive collection. We thank Dr Lindsay Popple for his determinations for specimens of *P. ligneocauda* at the ANIC and Dr Federica Turco for access. We are particularly grateful to Dr Lindsay Popple for his generous contribution of sound recordings for both species and his constructive comments that improved the manuscript.

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NEW AND POORLY KNOWN SPECIES OF *MOLOPHILUS* CURTIS CRANE FLIES FROM AUSTRALIA (DIPTERA: LIMONIIDAE)

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Abstract

Seven new species of Australian *Molophilus* Curtis are described: *M.* (*Molophilus*) *arte* **sp. n.**, *M.* (*Molophilus*) *breeae* **sp. n.**, *M.* (*Molophilus*) *buangensis* **sp. n.**, *M.* (*Molophilus*) *charliensis* **sp. n.**, *M.* (*Molophilus*) *lindi* **sp. n.**, M. (*Molophilus*) *paradisensis* **sp. n.** and *M.* (*Molophilus*) *pauli* **sp. n.** The new species belong in either the *plagiatus* group (*M.* (*M.*) *arte* and *M.* (*M.*) *buangensis*) or the *gracilis* group. In addition, the poorly known species *M.* (*Lyriomolophilus*) *lyratus* Alexander, 1927 is discussed and the hypopygium is figured.

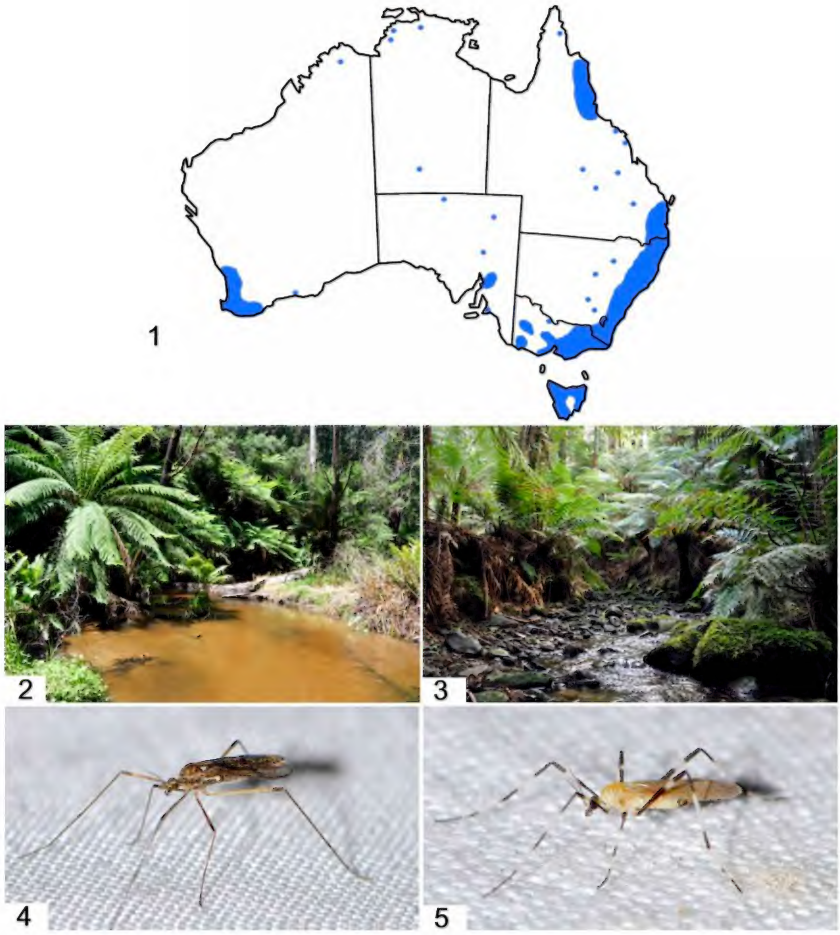
Introduction

Eminent British entomologist John Curtis first recognized the crane fly genus *Molophilus* Curtis in 1833 (Curtis 1833) and the genus now includes over one thousand species, present on all continents except Antarctica. The diversity of *Molophilus* is greatest in the Australasian region, with 439 species occurring across Australia, New Caledonia, New Zealand and Papua New Guinea (Oosterbroek 2017). Australia boasts more species of *Molophilus* than any other country or continent with 313 species recorded, including the seven species newly described here. With the exception of a single species, *M. (Molophilus) flavonotatus* Skuse, 1890, which is also known from New Zealand, the Australian species of *Molophilus* are all endemic.

Species of *Molophilus* were first described from Australia by Frederick Skuse in 1890 (Skuse 1890). Charles Alexander then described many species across multiple works from the early 1920s through to the late 1970s (Alexander 1921, 1922, 1923, 1924, 1927a-d, 1928, 1929a, b, 1930, 1931, 1934, 1942, 1944 and 1978) and Theischinger has since added many species and provided revisions of the Australian fauna in multiple works (Theischinger 1988a, b, 1992, 1994, 1996a, 1999, 2000 and 2012).

Species of *Molophilus* are recorded from all Australian states and territories (Fig. 1) and are most abundant and diverse along waterways in forested areas (Figs 2-3), particularly temperate and tropical rainforests. They are among the smaller members of Australia's crane fly fauna, with wing lengths generally not exceeding 8 mm. They are often plainly coloured with pale to dark shades of brown (Fig. 4); however some species have quite striking patterning (Fig. 5). They are readily distinguished from other crane flies by wing venation and the key provided by Theischinger (1996b) aids greatly in identification of *Molophilus* and other limoniid genera.

The Australian species of *Molophilus* are separated into seven subgenera: *Austromolophilus* Theischinger, *Bistromolophilus* Theischinger, *Diplomolophilus* Theischinger, *Lyriomolophilus* Theischinger, *Molophilus* Curtis, *Onychomolophilus* Theischinger and *Superbomolophilus* Theischinger. With the exception of subgenus *Molophilus*, all are endemic. The seven subgenera are separated using characters of the male hypopygium and a key to subgenera was provided by Theischinger (1992).



Figs 1-5. (1) Occurrence records of Australian *Molophilus*; (2-3) *Molophilus* habitat: (2) *M.* (*Austromolophilus*) *pulchripes* (Skuse, 1890), Little Yarra River, Poweltown, Victoria; (3) *M.* (*Molophilus*) *titania* Alexander, 1930, Tributary of Tarra River, Tarra Bulga National Park, Victoria; (4-5) general habitus of *Molophilus* species: (4) *M.* (*Austromolophilus*) *pulchripes*; (5) *M.* (*Molophilus*) *titania*.

Molophilus (*Molophilus*) is the most widespread and diverse subgenus in Australia and is further separated into three species groups: *M.* (*Molophilus*) *flavoannulatus* group of Theischinger (1992), *M.* (*Molophilus*) *gracilis* group and *M.* (*Molophilus*) *plagiatus* group, both of Theischinger (1988a). These species groups are also separated using characters of the male hypopygium and were included in the key provided by Theischinger (1992).

The present paper further adds to the knowledge of the Australian *Molophilus* by adding five species to the *M.* (*Molophilus*) *gracilis* group and two species to the *M.* (*Molophilus*) *plagiatus* group. In light of new material, the poorly known species *M.* (*Lyriomolophilus*) *lyratus* Alexander, 1927 is also discussed and the male hypopygium is figured.

Materials and methods

Specimens were collected by sweeping a hand net through vegetation and then preserved in 100% ethanol. As a result of this preservation, the coloration of specimens might have changed from the natural state. The illustrations of the male genitalia (hypopygium) are from specimens cleared in KOH and displayed in glycerol.

Specimens have been deposited in the Museum Victoria (NMV) collection or the Tasmanian Museum and Art Gallery (TMAG) collection. Specimens retained by the first author are kept in a vouchered research collection at the GHD water sciences laboratory in Melbourne to aid in ongoing survey work and for use in DNA barcoding studies. DNA sequencing efforts are ongoing; sequence and specimen data are stored in the Barcode of Life Data Systems (BOLD) database and, upon any future publication of genetic data, sequences will be published to GenBank.

Descriptive terminology is in accord with McAlpine (1981).

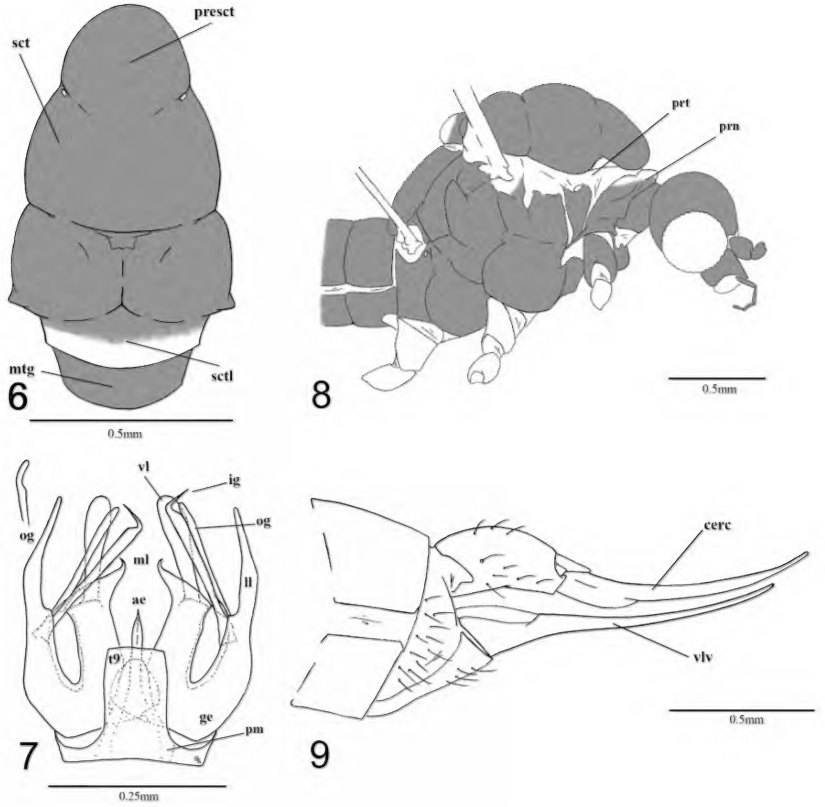
Abbreviations as used in figures: *ae*, aedeagus; *apm*, anepimeron; *ast*, anepisternum; *cerc*, cercus; *dl*, dorsal lobe of gonocoxite; *ge*, gonocoxite; *ig*, inner gonostylus; *kst*, katepisternum; *ll*, lateral lobe of gonocoxite; *ltg*, laterotergite; *mer*, meron; *ml*, medial lobe of gonocoxite; *mst*, metepisternum; *mtg*, mediotergite; *og*, outer gonostylus; *pm*, parameres; *presct*, prescutum; *prn,* pronotum; ; *prt,* paratergite; *sct*, scutum; *sctl*, scutellum; *t9*, tergite 9; *vl*, ventral lobe of gonocoxite; *vlv*, hypogynial valve.

New species of the *Molophilus* (*Molophilus*) *gracilis* group

Molophilus (*Molophilus*) *breeae* sp. n.

(Figs 6-10)

Material examined. Holotype ♂, Victoria, Mt Cole, along Cave Hill Creek by Ditchfield's Campground (-37.316°S, 143.271°E), 27 Apr 2013, Z. Billingham, NMV (MVT21939). *Paratypes*: 2 ♂♂, 3 ♀♀, same data as holotype, NMV (MVT21940, MTV22261-MTV22264); 2 ♂♂, same data as holotype, GHD (T6943, T6947).



Figs 6-9. *Molophilus* (*Molophilus*) *breeae* **sp. n.**: (6) thorax, dorsal view; (7) hypopygium, ventral view; (8) thorax, lateral view; (9) ovipositor, lateral view.

Description. Male (Fig. 10): body length (excluding antenna) 3.6 mm, wing length 5.0 mm. Head dark greyish black, antenna and palpus paler brownish grey. Antenna of moderate length, extending back to mediotergite. Pronotum with lateral edge pale yellow to white, otherwise dark greyish brown. Prescutum, scutum and mediotergite dark reddish brown. Scutellum dark reddish brown basally, somewhat paler yellowish brown dorsally (Fig. 6). Paratergite pale yellow to white, in combination with pale dorsal angle of pronotum forming a distinct pale stripe between terga and pleura. Cervical sclerite, propleuron and pleurites dark brown (Fig. 8). Forecoxa dark brown, mid and hind coxae, trochanters and basal 1/3 of femora pale brownish yellow, remainder of femora dark greyish brown. Tibiae and tarsi dark greyish brown. Wing pale grey with veins darker grey. Halter with stem and knob whitish. Abdomen dark greyish brown. Hypopygium (Fig. 7) brownish yellow, dorsal lobe of segment 9 rather narrow, subrectangular. Gonocoxite

with long slender lateral lobe, long wider ventral and short, strongly curved and pointed medial lobe. Outer gonostylus stick-shaped, inner gonostylus long, straight, subapically narrowed, apically hooked, wider than outer gonostylus. Parameres fused, aedeagus moderately wide and conical.

Female: colouration much as in male, wing length 5.5 mm. Ovipositor with apex of hypogynial valve reaching about 4/5 length of cercus (Fig. 9).

Discussion. The long thin lateral and rather long ventral lobe of the gonocoxite, together with the straight outer and long, straight, apically hooked inner gonostylus, indicate close affinity of *M.* (*M.*) *breeae* sp. n. with *M.* (*M.*) *difficilis* Alexander, 1927, *M.* (*M.*) *exsertus* Alexander, 1927, *M.* (*M.*) *spiculistylatus* Alexander, 1930 and *M.* (*M.*) *insertus* Theischinger, 1992. Whereas in these four species the outer gonostylus is club-shaped and wider than the inner gonostylus and the medial lobe of the gonocoxite ends in a straight spike, the inner gonostylus is wider than the outer gonostylus and the apex of the medial lobe of gonocoxite ends in a strongly curved hook in *M.* (*M.*) *breeae* sp. n.

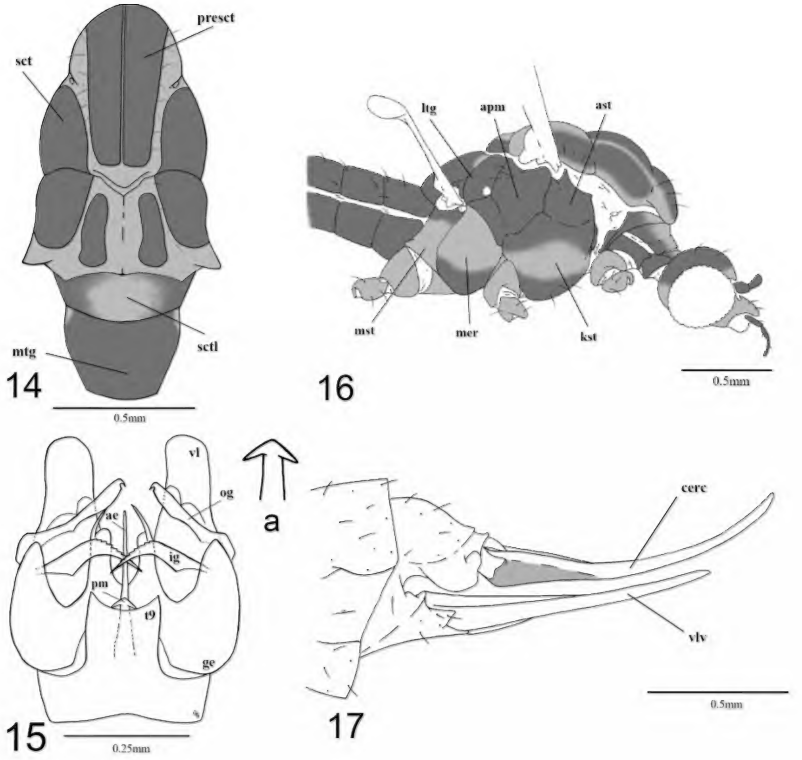
Etymology. This species is dedicated to Bree Cawsey, whose encouragement and support has been invaluable in the first author's studies of Australian crane flies.

Figs 10-13. General habitus of *Molophilus* spp: (10) *M.* (*Molophilus*) *breeae* **sp. n.**, male; (11) *M.* (*Molophilus*) *charliensis* **sp. n.**, male; (12) *M.* (*Molophilus*) *lindi* **sp. n.**, male; (13) *M.* (*Molophilus*) *buangensis* **sp. n.**, male.

***Molophilus* (*Molophilus*) *charliensis* sp. n.**

(Figs 11, 14-17)

Material examined. Holotype ♂, Victoria, Alpine National Park, Charlie Creek (-36.731°S, 148.064°E), 30 Nov 2015, Z. Billingham, NMV (MVT22254). *Paratype* ♀, same data as holotype, NMV (MVT22255).



Figs 14-17. *Molophilus (Molophilus*) *charliensis* **sp. n.**: (14) thorax, dorsal view; (15) hypopygium, ventral view, parameres (a) inset; (16) thorax, lateral view; (17) ovipositor, lateral view.

Description. Male (Fig. 11): body length (excluding antenna) 3.6 mm, wing length 6.5 mm. Head dark greyish brown at apex, paler yellowish brown anteriorly and ventrally, antenna and palpus greyish brown. Antenna extending back to prescutal suture. Pronotum with dorsal angle yellowish brown, otherwise greyish brown. Prescutum and scutum yellowish brown with two darker brown stripes narrowly separated medially with yellowish brown arising at anterior margin of prescutum, extending onto scutum and terminating before transverse suture, scutum with an additional dark brown stripe on lateral angle arising at prescutal pit and extending across transverse

suture onto scutal lobe, scutal lobes each with an additional dark brown medial marking narrowly separated from the more lateral marking. Scutellum pale brownish yellow with anterolateral angles darker. Mediotergite dark greyish brown (Fig. 14). Cervical sclerite and propleuron greyish brown. Anepisternum and anepimeron greyish brown. Laterotergite greyish brown with a pale whitish yellow spot basally. Katepisternum greyish brown dorsally, yellowish brown medially and greyish brown basally. Meron yellowish brown dorsally, greyish brown basally Metepisternum greyish brown dorsally, yellowish brown basally (Fig. 16). Coxae and trochanters yellowish brown. Femora, tibiae and tarsi dark greyish brown. Wing pale brownish grey with veins darker brown. Halter with stem pale brownish grey, knob pale whitish yellow. Abdominal segments 1-8 dark greyish brown, segment 9 yellowish brown. Hypopygium (Fig. 15) brownish, dorsal lobe of segment 9 quadrate, caudal margin shallowly concave. Gonocoxite with dorsolateral lobe of moderate size and with apex narrowly rounded, with medial lobe of moderate size, rather bulky and dorsally produced into a backward directed slightly medially curved spine and with ventral lobe long, wide, largely parallel sided and apically widely rounded. Inner gonostylus sickle-shaped with base moderately wide and apex narrowly pointed, outer edge of apical half serrated with fewer than ten serrations. Outer gonostylus an almost straight, somewhat club-shaped hook. Aedeagus long and thin; parameres double-hooked (Fig. 15a).

Female: size and colouration much as in male. Ovipositor with apex of hypogynial valve reaching about 3/4 length of cercus (Fig. 17).

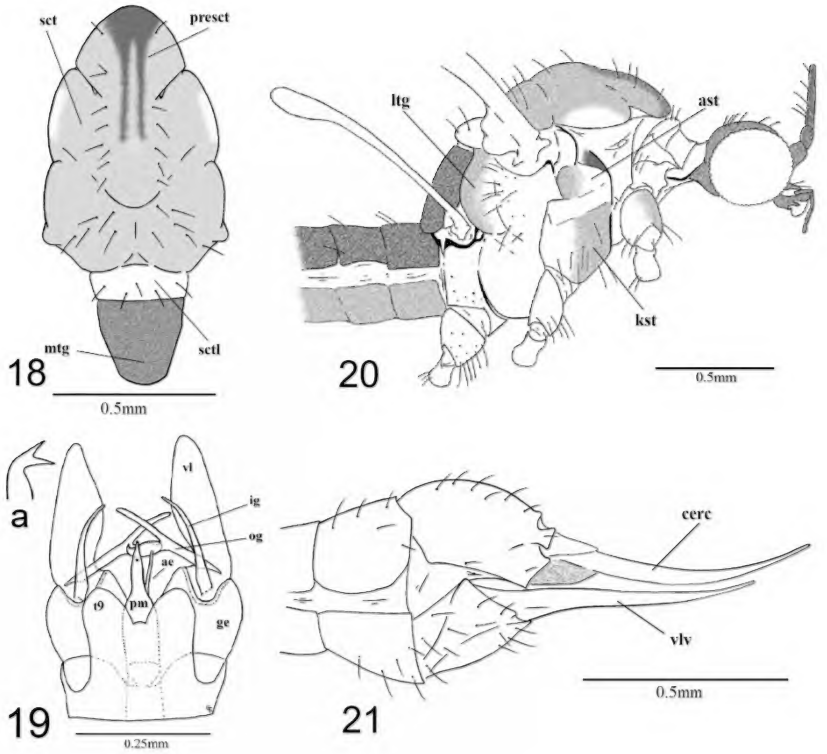
Discussion. The male terminalia of *M.* (*M.*) *charliensis* sp. n are close to those of *M.* (*M.*) *immutatus* Alexander, 1929, *M.* (*M.*) *permutatus* Alexander, 1931 and *M.* (*M.*) *pictor* Alexander, 1934, all from Victoria, plus *M.* (*M.*) *praelatus* Alexander, 1927 from the Blue Mountains in New South Wales. *Molophilus* (*M.*) *charliensis* sp. n. shares the produced medial lobe of the gonocoxite only with *M.* (*M.*) *immuatus* and is considered to be its closest ally. However, *M.* (*M.*) *charliensis* sp. n. lacks a distinct spine at the outer edge of the inner gonostylus and has part of its outer edge serrate, while *M.* (*M.*) *immutatus* possesses a spine at the outer edge of its otherwise entirely smooth inner gonostylus.

Etymology. This species is named after the Charlie Creek campground at the type locality.

***Molophilus* (*Molophilus*) *lindi* sp. n.**

(Figs 12, 18-21)

Material examined. Holotype ♂, Victoria, Yarra Ranges National Park, tributary of Alderman Creek (-37.721°S, 145.940°E), 28 Apr 2014, Z. Billingham, NMV (MVT21941). *Paratypes*: 5 ♂♂, 1 ♀, same data as holotype; NMV (MVT21942 & MTV22271-MTV 22275); 1 ♂, Victoria, Yarra Ranges National Park, tributary of Alderman Creek (-37.721°S, 145.940°E), 1 May 2013, Z. Billingham, GHD (T6884).



Figs 18-21. *Molophilus* (*Molophilus*) *lindi* **sp. n.**: (18) thorax, dorsal view; (19) hypopygium, ventral view, with lateral view of parameres (a) inset; (20) thorax, lateral view; (21) ovipositor, lateral view.

Description. Male (Fig. 12): body length (excluding antenna) 3.9 mm, wing length 5.8 mm. Head, antenna and palpus pale greyish brown. Antenna 16 segmented with flagellomeres markedly elongate, terminal flagellomere somewhat shorter, total length exceeding body length. Pronotum pale greyish brown. Prescutum and scutum brownish with lateral edge of scutum paler yellowish brown, a darker greyish brown marking arising at anterior margin of prescutum and continuing onto scutum as two stripes separated medially with yellowish brown and terminating beyond prescutal suture. Scutellum pale yellowish brown. Mediotergite darker greyish brown (Fig. 18). Cervical sclerite and propleuron pale greyish brown. Pleurites pale yellowish brown, darker brownish markings along dorsal edge of anepisternum, anterior half of katepisternum and posterior half of laterotergite (Fig. 20). Forecoxa greyish brown, mid and hind coxae and trochanters pale yellowish brown. Femora, tibiae and tarsi greyish brown. Wing pale brownish grey with veins darker

brownish grey and abundant macrotrichia. Halter with stem brownish grey, knob pale whitish yellow. Abdominal tergites 1-8 dark brownish grey, sternites paler, segment 9 pale brownish yellow. Hypopygium (Fig. 19) pale brownish yellow, dorsal lobe of segment 9 rather wide, distinctly bilobed. Gonocoxite with large ventral lobe, medial and lateral lobes only minimally developed. Outer gonostylus forked at about half-length into shorter broader hooked and longer narrower slightly and evenly curved prong; inner gonostylus a slightly but evenly curved slender smooth tapering rod. Parameres strongly developed, fused, ending in a cone that forks into two rather pointed prongs aligned along mid-line (Fig. 19a); aedeagus very slim.

Female: colouration much as in male; antenna shorter, extending back to the mid abdomen; wing length 5.0 mm. Ovipositor with apex of hypogynial valve reaching about 3/4 length of cercus (Fig. 21).

Discussion. The bilobed dorsal lobe of segment 9, the large ventral lobe of the gonocoxite, the long-pronged fork of the outer gonostylus and the fused, strongly sclerotized parameres indicate close affinity of *M.* (*M.*) *lindi* sp. n. with *M.* (*M.*) *extensicornis* Alexander, 1934, *M.* (*M.*) *tasioceroides* Alexander, 1930, *M.* (*M.*) *maroondah* Theischinger, 1992 and *M.* (*M.*) *wilsoni* Alexander, 1929, all from Victoria. Whereas these four species have the inner gonostylus short and stout or sausage-shaped and setose, and the parameres forking into small lateral prongs, the inner gonostylus is long, very slender, conical and smooth and the fork of the parameres has both prongs aligned along the midline in *M.* (*M.*) *lindi* sp. n.

Etymology. This species is dedicated to Dr. Peter Lind, who assisted in the collection of the type material and has assisted greatly in the first author's studies of Australian crane flies.

***Molophilus* (*Molophilus*) *paradisensis* sp. n.**

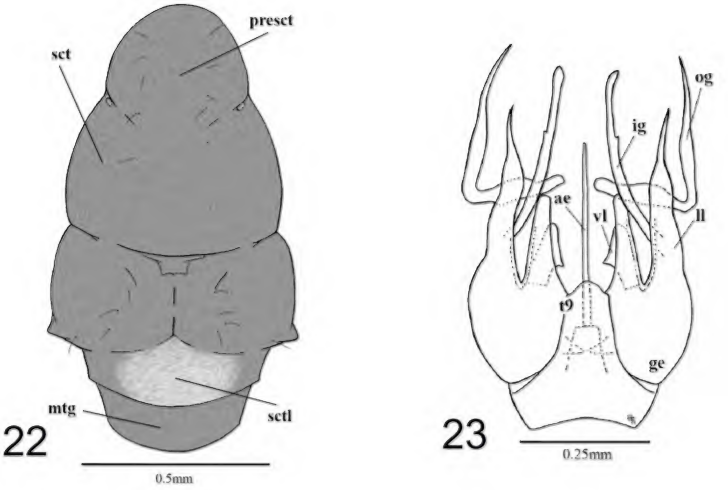
(Figs 22-25)

Material examined. Holotype ♂, Victoria, Alpine National Park, tributary of Stony Creek at Little Paradise Falls (-36.867°S, 146.456°E), 29 Sept 2014, Z. Billingham, NMV (MVT22252). *Paratypes*: 2 ♂♂, Jack Creek at Fassifern Falls (-37.101°S, 145.455°E), 20 Oct 2014, Z. Billingham, NMV (MVT22276) and GHD (T10714).

Description. Male (Fig. 25): body length (excluding antenna) 4.1 mm, wing length 5.3 mm. Head pale yellowish brown with large central dark brown area on vertex. Antennal pedicel, scape and first flagellomere yellowish brown, remainder of flagellum and palpus greyish brown. Antenna extending back to wing root. Pronotum with dorsal angle pale yellow to white, otherwise dark greyish brown. Prescutum and scutum dark reddish brown. Scutellum yellowish brown with lateral angles greyish brown. Mediotergite greyish brown (Fig. 22). Paratergite pale yellow to white, in combination with pale dorsal angle of pronotum, forming a distinct pale stripe between terga and pleura. Cervical sclerite and pleurites dark brown (Fig. 24). Fore

and midcoxae dark brown, hindcoxa, trochanters and basal 1/3 of femora brownish yellow, distal 2/3 of femora darkening to greyish brown at tips. Tibiae brown basally, darkening to greyish brown at tips. Fore tibia with thickened sub-basal ring. Tarsi dark greyish brown. Wing with membrane and veins pale brownish grey, a darker grey cloud extending from pterostigma along R1 to costa. Halter with stem pale grey, knob pale whitish yellow. Abdominal segments 1-8 dark brownish grey, segment 9 brownish yellow. Hypopygium (Fig. 23) brownish yellow, dorsal lobe of segment 9 narrow sub-rectangular, caudal margin convex. Gonocoxite with dorsolateral lobe long, slim with lateral margins slightly sinuous and apex a slim spike, with medial lobe simple and rather slim, and with ventral lobe flat and short, with rather pointed medial 'nose' and with apex rounded. Inner gonostylus a long slender slightly curved rod with a small lateral denticle at about 2/3 length and apex slightly thickened and rather obtusely pointed. Outer gonostylus a slender, almost perpendicularly angled rod, inner end of transverse portion rather narrowly truncate, outer portion a slightly sinuous sharp spike. Aedeagus long and thin, parameres truncate.

Female: unknown.

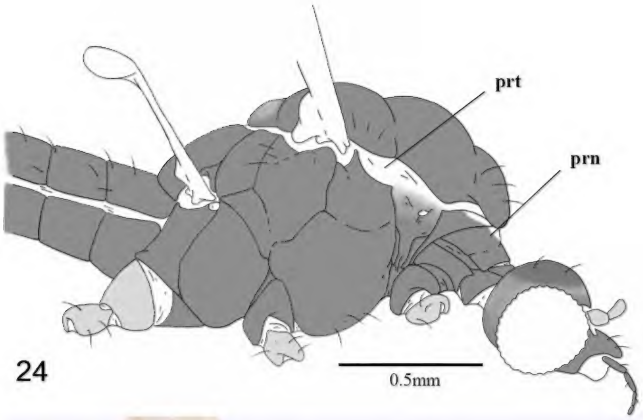


Figs 22-23. *Molophilus* (*Molophilus*) *paradisensis* **sp. n.**: (22) thorax, dorsal view; (23) hypopygium, ventral view.

Discussion. The spine-shaped apex of the dorsolateral lobe of gonocoxite and perpendicularly angled outer gonostylus of *M.* (*M.*) *paradisensis* sp. n. is shared only with *M.* (*M.*) *reductus* Alexander, 1927 and *M.* (*M.*) *verticalis* Alexander, 1927, both recorded from Victoria and Tasmania. *Molophilus* (*M.*) *paradisensis* sp. n. can be distinguished from these two species by the

absence of an additional inner portion of the outer gonostylus and by the much more basal position of the denticle on the inner gonostylus. The simple dorsolateral lobe of the gonocoxite of *M.* (*M.*) *reductus* versus being bifid in *M.* (*M.*) *verticalis*, makes *M.* (*M.*) *reductus* appear the closest ally of *M.* (*M.*) *paradisensis* sp. n.

Etymology. This species is named after the Little Paradise waterfall at the type locality.

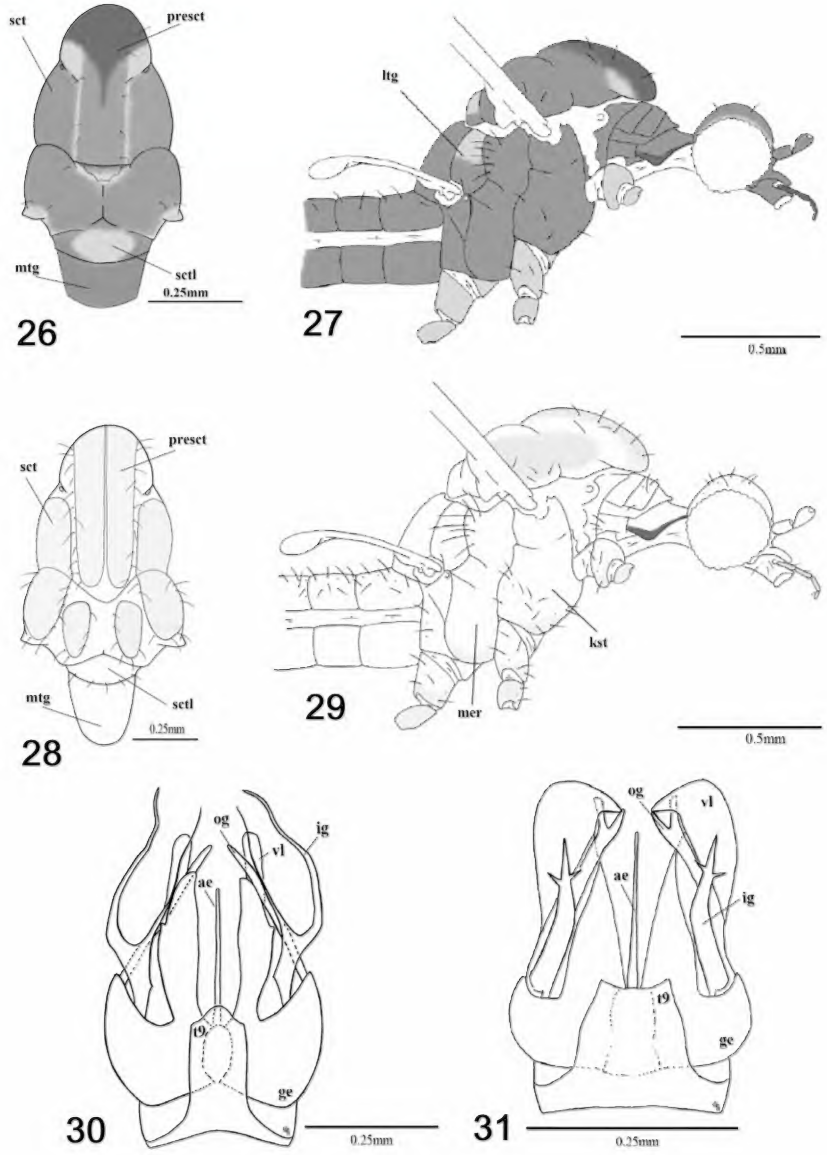


Figs 24-25. *Molophilus* (*Molophilus*) *paradisensis* **sp. n.**: (24) thorax, lateral view; (25) general habitus, male.

***Molophilus* (*Molophilus*) *pauli* sp. n.**

(Figs 26-27, 30)

Material examined. Holotype ♂, Victoria, Ada State Forest, LaTrobe River (-37.880°S, 145.889°E), 04 Jan 2014, Z. Billingham, NMV (MVT22253). *Paratype* ♂, Victoria, Ada State Forest, LaTrobe River (-37.880°S, 145.889°E), 17 Jan 2016, Z. Billingham, GHD (T13287).



Figs 26-31. (26-27) *Molophilus* (*Molophilus) pauli* **sp. n.**: (26) thorax, dorsal view; (27) thorax, lateral view. (28-29) *M.* (*Molophilus*) *arte* sp. n.: (28) thorax, dorsal view; (29) thorax, lateral view. (30) *M.* (*Molophilus) pauli* **sp. n.**, hypopygium, ventral view. (31) *M.* (*Molophilus*) *arte* **sp. n.**, hypopygium, ventral view.

Description. Male: body length (excluding antenna) 2.8 mm, wing length 3.5 mm. Head dark greyish brown, antennal pedicel, scape and basal five flagellomeres paler brown, remainder of flagellum missing, palpus greyish brown. Pronotum brown. Prescutum yellowish brown with a broad brown stripe extending onto scutum and terminating at transverse suture, the stripe narrowly bordered by yellowish brown, additionally with darker greyish brown triangular marking with base arising at anterior margin of prescutum and apex drawn into a point terminating beyond prescutal suture; scutum otherwise brown with posterolateral angles yellowish brown. Scutellum yellowish brown with lateral angles darker brown. Mediotergite brown (Fig. 26). Cervical sclerite brown. Pleurites brown with laterotergite yellowish brown dorsally (Fig. 27). Coxae and trochanters pale brownish yellow. Femora, tibiae and tarsi greyish brown. Wing membrane and veins brownish grey. Halter with stem brownish grey, knob pale grey. Abdominal segments 1-8 brownish grey, segment 9 brown. Hypopygium (Fig. 30) brown, dorsal lobe of segment 9 rather narrow, distal edge subrectangular. Gonocoxite with dorsolateral lobe of moderate size and with apex narrowly rounded, with medial lobe large with a dorsal denticle beyond mid-length and with apex not markedly produced, and with ventral lobe simple, long, slim, largely parallel sided and with apex rounded. Inner gonostylus a short-based fork with two very long and thin prongs, outer prong somewhat longer and thicker, inner prong in apical half almost hair-like, both variously sinuously curved. Outer gonostylus long, thin, almost straight with apex somewhat attenuated. Aedeagus long and thin; parameres oval.

Female: unknown.

Discussion. The male terminalia of *M.* (*M.*) *pauli* sp. n. are closest to *M.* (*M.*) *forceps* Alexander, 1927 from the Blue Mountains in New South Wales. It can be distinguished from this species by the presence of a dorsal denticle on the apically shorter medial lobe of the gonocoxite and by the much longer, thinner and irregularly curved prongs of the inner gonostylus.

Etymology. This species is dedicated to Paul Billingham, who assisted in the collection of the holotype material and whose support of the first author's studies is greatly appreciated.

New species of the *Molophilus* (*Molophilus*) *plagiatus* group

Molophilus (*Molophilus*) *arte* sp. n.

(Figs 28-29, 31)

Material examined. Holotype ♂, Victoria, Arte River Flora Reserve, Arte River at Arte River Falls (-37.571°S, 148.766°E), 07 Jan 2015, Z. Billingham, NMV (MVT22250). *Paratype* ♂, same data as holotype, GHD (T10529).

Description. Male: body length (excluding antenna) 3.8 mm, wing 4.4 mm. Head, antennal pedicel and scape pale whitish yellow, antennal flagellum and palpus dark greyish brown. Antenna extending back to wing root. Pronotum

whitish. Prescutum, scutum, scutellum and mediotergite pale whitish yellow with two yellowish brown stripes narrowly separated medially with whitish yellow arising at anterior margin of prescutum, extending onto scutum and terminating before transverse suture, scutum with an additional yellowish brown stripe on each lateral angle arising at prescutal pit and extending across transverse suture onto scutal lobe, scutal lobes each with an additional yellowish brown medial marking narrowly separated from the more lateral marking (Fig. 28). Cervical sclerite and pleurites pale whitish yellow, katepisternum and meron darkening to pale yellowish brown basally (Fig. 29). Coxae whitish yellow dorsally, darkening to yellowish brown basally. Trochanters, femora and tibiae pale yellowish brown, tarsi greyish brown. Wing hyaline with veins pale yellowish brown. Halter with stem pale yellowish brown, knob pale whitish yellow. Abdominal segments 1-9 and hypopygium pale whitish yellow. Hypopygium (Fig. 31) pale whitish yellow, dorsal lobe of segment 9 quadrate, caudal margin slightly concave. Gonocoxite with dorsolateral lobe very small, medial lobe not prominent and ventral lobe large, largely parallel sided and apically strongly bowed medially ending in a substantial beak. Inner gonostylus of moderate size, widely bowed at about mid-length, with basal half about cylindrical and apical half conical ending in a long narrow point, a short thin subapical spike each side. Outer gonostylus rather slim, largely parallel sided, with apex forked into two similar prongs. Aedeagus long and thin; parameres oval to truncate.

Female: unknown.

Discussion. The male terminalia of *M.* (*M.*) *arte* sp. n look closest to numerous species around *M.* (*M.*) *flavidellus* Alexander, 1930 from Victoria. It can be distinguished from all of them by the particular shape of its trifid inner gonostylus.

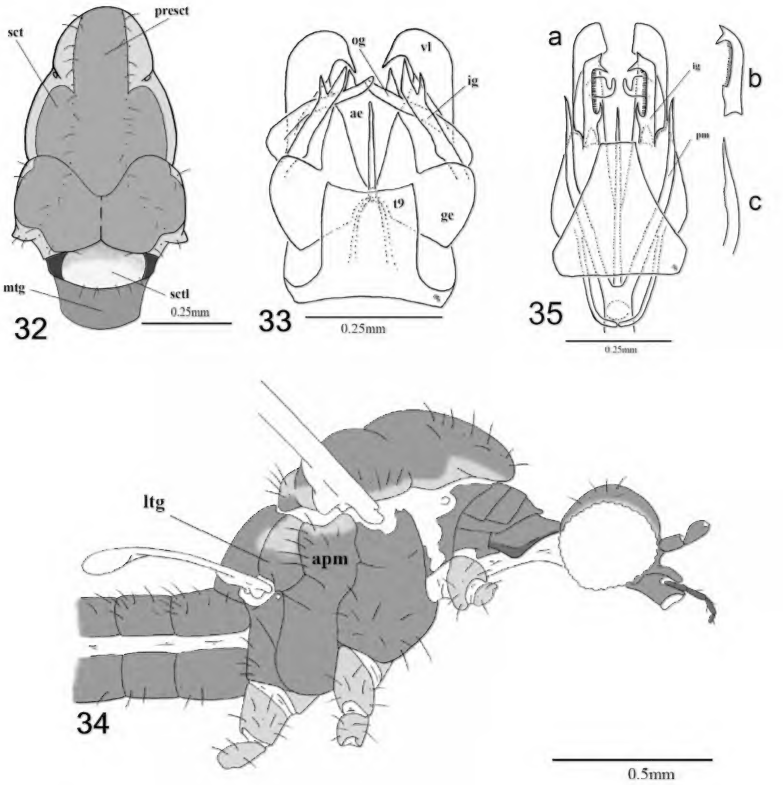
Etymology. This species is named after the Arte River waterfall at the type locality and is to be treated as a noun in apposition.

***Molophilus* (*Molophilus*) *buangensis* sp. n.**

(Figs 13, 32-34)

Material examined. Holotype ♂, Victoria, Yarra Ranges National Park, Cement Creek at Rainforest Gallery (-37.711°S, 145.709°E), 17 Jan 2016, Z. Billingham, NMV (MVT22251). *Paratypes*: 2 ♂♂, same data as holotype, NMV (MVT22270) and GHD (T14549); 1 ♂, Victoria, Dandenong Ranges National Park, Hardys Creek off Lyrebird Walking Track (-37.890°S, 145.373°E), 10 Jan 2016, Z. Billingham, NMV (MVT22269); 4 ♂♂, Victoria, Yarra Ranges National Park, Mt Donna Buang Rainforest Gallery (-37.711° S, 145.709° E), 13 Jan 2016, Z. Billingham, NMV (MVT22265-MVT22268).

Description. Male (Fig. 13): body length (excluding antenna) 3.6 mm, wing length 4.1 mm. Head greyish brown with narrow yellow margin around eye, antenna and palpus greyish brown. Antenna of moderate length, extending



Figs 32-35. (32-34) *Molophilus* (*Molophilus*) *buangensis* **sp. n.**: (32) thorax, dorsal view; (33) hypopygium, ventral view; (34) thorax, lateral view. (35) *Molophilus* (*Lyriomolophilus*) *lyratus*: (a) hypopygium, ventral view with the inner gonostylus (b) and parameres (c) of *M. (L.*) *buckenbowra* inset.

back to mediotergite. Pronotum greyish brown. Prescutum and scutum brown with anterior, lateral and posterolateral angles paler yellowish brown. Scutellum pale yellowish brown, somewhat darker yellowish brown anteriorly and with lateral angles dark greyish brown. Mediotergite brown with small paler yellowish brown markings on anterolateral edges (Fig. 32). Cervical sclerite and pleurites largely greyish brown, anepimeron and laterotergite paler yellowish brown dorsally (Fig. 34). Coxae and trochanters pale brownish yellow. Femora, tibiae and tarsi greyish brown. Wing pale brownish grey with veins darker grey. Halter with stem brownish grey, knob pale whitish yellow. Abdominal segments 1-8 dark brownish grey, segment 9 brownish yellow. Hypopygium (Fig. 33) brownish yellow, gonocoxite with dorsolateral and medial lobe not prominent and with ventral lobe large, largely parallel sided and apically strongly bowed dorsomedially, ending in a

substantial beak/hook. Inner gonostylus of moderate length, almost straight, forked at about 2/3 length, each fork with sharply pointed apex. Outer gonostylus largely parallel-sided, with apex forked. Aedeagus of medium length and thin; parameres indistinct with apex apparently narrowly rounded.

Female: unknown.

Discussion. The combination of the pointed hooked ventral lobe and the lack of distinct dorsolateral and medial lobes of the gonocoxite, the clearly forked inner gonostylus, the simple parameres and the short aedeagus of *M.* (*M.*) *buangensis* sp. n. strongly resemble *M.* (*M.*) *bogongensis* Alexander, 1929, which is considered its closest ally. The ventral lobe of the gonocoxite of *M.* (*M.*) *buangensis* sp. n. appears more strongly hooked and more sharply pointed than in *M.* (*M.*) *bogongensis* and the inner gonostylus of *M.* (*M.*) *buangensis* sp. n. appears straight *vs* distinctly curved in *M.* (*M.*) *bogongensis*.

Etymology. This species is named after the type locality, Mt Donna Buang.

A poorly known species of *Molophilus* (*Lyriomolophilus*)

Molophilus (*Lyriomolophilus*) *lyratus* Alexander, 1927

(Fig. 35)

Material examined. 1 ♂, Tasmania, South Bruny National Park, Blighs Creek (-43.379°S, 147.346°E), 06 Feb 2016, Z. Billingham, TMAG (F57221).

Discussion. Theischinger (1988b) based *Lyriomolophilus* on *M.* (*Lyriomolophilus*) *buckenbowra* Theischinger, 1988, a species that he considered very close to *M.* (*Lyriomolophilus*) *lyratus* Alexander, 1927 (Theischinger 1992). Alexander (1927b) did not provide an illustration of the male hypopygium of *M.* (*L.) lyratus* and, while Theischinger (1992) provided illustrations of all other *M.* (*Lyriomolophilus*) species, a specimen of *M.* (*L.*) *lyratus* was not available at that time. Fortunately, a single male of *M.* (*L.*) *lyratus* was recently collected by the first author, allowing for illustration and interpretation of this species.

The close similarity of *M.* (*L.*) *lyratus* to, and differences from, *M.* (*L.*) *buckenbowra* are now clear. Whereas Alexander (1927) described the lyriform phallosomic structure (parameres) of *M.* (*L.*) *lyratus* as 'with the two arms slender, narrowed gradually to the acute tips' and the inner gonostylus with 'lower face with a conspicuous sub-basal spine directed toward the apex of the style', the descriptions of Theischinger (1988) for these structures in *M.* (*L.*) *buckenbowra* were 'both arms with a series of acute, nearly appressed teeth along mesal face at about four-fifths length' and 'with base expanded medially and ending in a small, about right-angled corner'. Fig. 35 shows that Alexander's and Theischinger's descriptions are accurate and also that the hypopygium of *M.* (*L.*) *lyratus* is markedly more slender than that of *M.* (*L.*) *buckenbowra*.

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NESTING BIOLOGY OF AN AUSTRALIAN POTTER WASP, *DELTA LATREILLEI* (SAUSSURE) (HYMENOPTERA: VESPIDAE: EUMENINAE)

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Abstract

Delta latreillei (Saussure), a large potter wasp, is widespread and abundant across tropical and subtropical Australia and has been accidentally introduced into New Zealand. Late in the dry seasons of 2004 and 2007, at a site near Katherine, Northern Territory, we studied marked wasps at 12 selected focal nests and dissected the nests. Like other mud-daubing solitary wasps, females carry mud in their jaws to form cells, then switch to using their legs to transport prey under their bodies for their individually housed offspring. Their nests have unusually thick outer walls that might function both as waterproofing and as fortification against predation and females will assiduously repair experimentally induced damage. These walls do not protect against persistent parasites such as chrysidid wasps that appear to monitor provisioning activity to facilitate their attack through the open nest entrance, but frequent inspection visits undertaken by female *D. latreillei* provide opportunities to find and destroy parasites' eggs and larvae. These visits also allowed females to replace lightly paralysed prey that had crawled away; in experimental trials, prey placed outside nests were ignored during cell construction but shoved back inside even already full nests after provisioning had begun.

Introduction

Potter or mason wasps belonging to the Eumeninae are found throughout the world and play important roles in terrestrial ecosystems as predators of caterpillars and other insects. *Delta* de Saussure is one of the most cosmopolitan eumenine genera, having been recorded from all zoogeographical regions. Carpenter *et al.* (2010) listed 19 species for the world. Biological studies on non-Australian *Delta* species include Gess and Gess (2014), Mader (2003), Menke and Stange (1986) and Yamane and Matsuura (1991).

Delta latreillei (Saussure), one of Australia's larger potter wasps, is widely distributed (Cardale 1985; *https://bie.ala.org.au/species/urn:lsid:biodiversity.org.au:afd.taxon:8ff04785-58d1-4944-984a-1703df7d7375*), being recorded from Victoria, New South Wales, Queensland, Western Australia and the Northern Territory. Strongly synanthropic, it commonly searches in and around buildings, constructing its domed hemispherical mud nests on a variety of substrates in both rain-protected and open locations. Nest construction has been described briefly for this species in Queensland (Girault 1914) and Victoria (Donnell 1944) and in New Zealand, where it has been accidentally introduced (Donovan 1995).

In general outline, nesting *D. latreillei* wasps behave in ways similar to other species of eumenines. They first collect water, then use it to wet suitable soil collected from a nearby site, then carry successive loads of the moistened soil in their mouths to a protected location where these are systematically applied

to make oval-shaped cells in which offspring develop individually. Each cell is built up until an opening just large enough to admit the female's abdomen remains, at which point oviposition occurs. Then the cell is mass-provisioned and closed.

Here, we report a more detailed behavioural study of *Delta latreillei*, with new information on nest construction and provisioning, behavioural plasticity and parasitism by sarcophagid flies and three species of chrysidid wasps.

Material and methods

We studied *Delta latreillei* over the course of two late dry season periods (November-December 2004, November-December 2007) at the Northern Territory Rural College, Charles Darwin University (14°22.454'S 132°09.403'E), about 15 kilometres northwest of Katherine. Most observations were of nests constructed in an open-air carport beneath a raised house on the college campus.

Twelve nests (five in 2004 and seven in 2007) were observed and dissected. Paint-marked wasps and selected focal nests were observed over several days and behaviour was documented with digital photographs. See Matthews and Matthews (2009) for additional details on the study site and methods.

Biology and life history

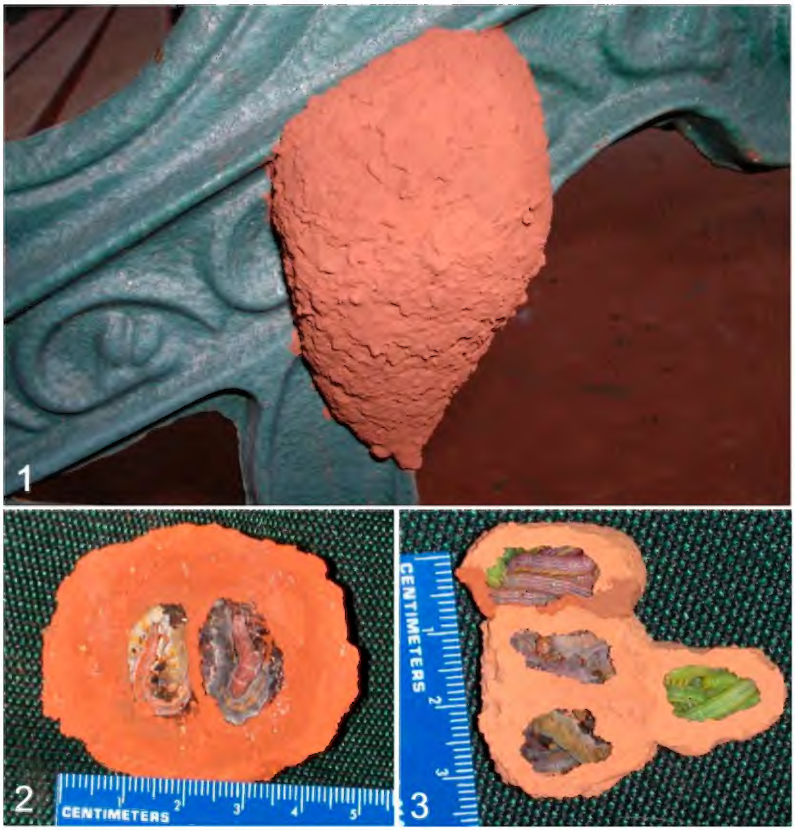
Nest location and form

Nests were invariably isolated from one another, never clustered as often occurs in other mud-dauber wasps (*e.g. Sceliphron* Klug, *Trypoxylon* Latreille). Nest substrates varied, ranging from the inside of a bicycle helmet to the wrought iron rail of a park bench (Fig. 1), the inside corner of a shelf unit and the open floor of a laundry area.

After the first two cells are placed end to end, the female places the third adjacent to the first and the fourth adjacent to the second, continuing in this manner until it has produced a rectangular array of cells on the substrate. A second layer of cells is then added atop the others, nestled in the crevices that have naturally formed between the cells in these basal rows. Thus, as the nest develops, it assumes the rough architectural form of a domed ovoid hemisphere. The irregular spaces that remain between cells are then filled with mud and additional layers, here termed outer coating (Fig. 2), are applied to form 7-12 mm thick exterior walls that obscure the actual position of the cells within. At its highest point a typical finished nest rises about 30 mm from the substrate. The basal footprint for the 8 completed nests in our study averaged 44 mm by 71.4 mm. The smallest footprint measured 40 mm by 52 mm; this nest held three cells. The largest footprint measured 60 mm by 120 mm; this nest held 14 cells. Cell dimensions depend on the topography of the substrate but cells typically were longer than wide, ranging from 16-25 mm long and 9-15 mm wide (Fig. 3).

Nest construction behaviour

Nest initiation was observed once. At 0745h we saw a female *Delta* flying about in the laundry area, landing here and there and investigating various surfaces. It did this for 22 minutes, with its flight patterns becoming progressively more restricted to the top of a shelving unit. A sarcophagid satellite fly shadowed its every movement during this investigation, but was absent when the wasp returned 10 minutes later. The wasp then spent 16 minutes intensively inspecting the top of the shelf unit. Upon departing, it performed a series of ever expanding circular orientation flights that covered most of the room area. It returned again 4 minutes later, staying only briefly before departing for 3 minutes more.



Figs 1-3. Nests of *Delta latreillei*: (1) a recently completed nest containing 14 cells on the metal seat support of a park bench; (2) the underside of a small nest showing the thick outer coating of mud added after provisioning the original cells; (3) an incomplete four-celled nest showing prey caterpillars packed into the oblong or oval cells typical of this species.

At 0850h, the wasp returned with its first load of mud and thereafter worked rapidly, bringing in 10 loads by 0928h. Then it disappeared for about 45 minutes before resuming the construction of the first cell, to which it rapidly added 7 more loads and formed a dome-shaped mud cell with a thorax-sized opening at the top. Thus, 17 trips were required to complete the first cell. The average time per trip in this example was 5m25s (range 2m3s-15m24s).

In all, we observed the complete cell construction process (Fig. 4) six times (two different nests). For completion, each cell necessitated 10-17 mud-carrying trips, each averaging just under five minutes (mean = 4m24s, range 51s-48m51s, n = 86). Note that 48m51s was an outlier, as the next longest mud trip was just over 15 minutes.

Our observations suggest that females can construct one or two cells per day; one nest observed for 8 days had 10 cells constructed during that time. However, the rate of cell construction no doubt varies depending on local conditions such as proximity to suitable soil or water sources and availability of suitable prey. One marked female was observed to repeatedly return to a soil site that was 17 m from the nest; the water source was found to be a small puddle 1.5 m from the soil source and the wasp was observed to make about one visit to the puddle for every 8-10 trips for soil.

In contrast to Australia's largest mud-daubers, species of *Abispa* Mitchell, in which males remain in long-term association with nesting females (Matthews and Matthews 2009), *D. latreillei* mating occurs off-site and only females participate in nesting.

Oviposition

Oviposition occurred in the empty cell immediately after the last load of cell-forming mud was applied (Fig. 5). The wasp inserted its abdomen through the cell opening and suspended an egg by a short (1-1.4 mm) filament placed 6-7 mm from the cell opening. Oviposition averaged 1m18s (range 45s-2m13s, n = 5). Eggs measured 3.5-3.7 mm long by 0.6-1.0 mm diameter (n = 3). We were unable to monitor brood development, but previous studies on *D. latreillei* (Girault 1914, Donnell 1944) and information on related species (Yamane and Matsuura 1991) indicate that brood development requires approximately 50-52 days.

Provisioning

Immediately after completing the cell and ovipositing within it, the female began provisioning. We observed 60 trips for prey for 6 cells in two different nests. These hunting trips averaged just under 15 minutes (range 3m26s-42m41s). Prey were large caterpillars of several different species. Most apparently belonged to the Geometridae or Noctuoidea (Lepidoptera), the same groups of prey recorded for this wasp in New Zealand (Donovan 1995) and for *D. pyriforme* (Fabricius) in Japan (Yamane and Matsuura 1991). Fig. 3 shows prey in four recently completed cells.

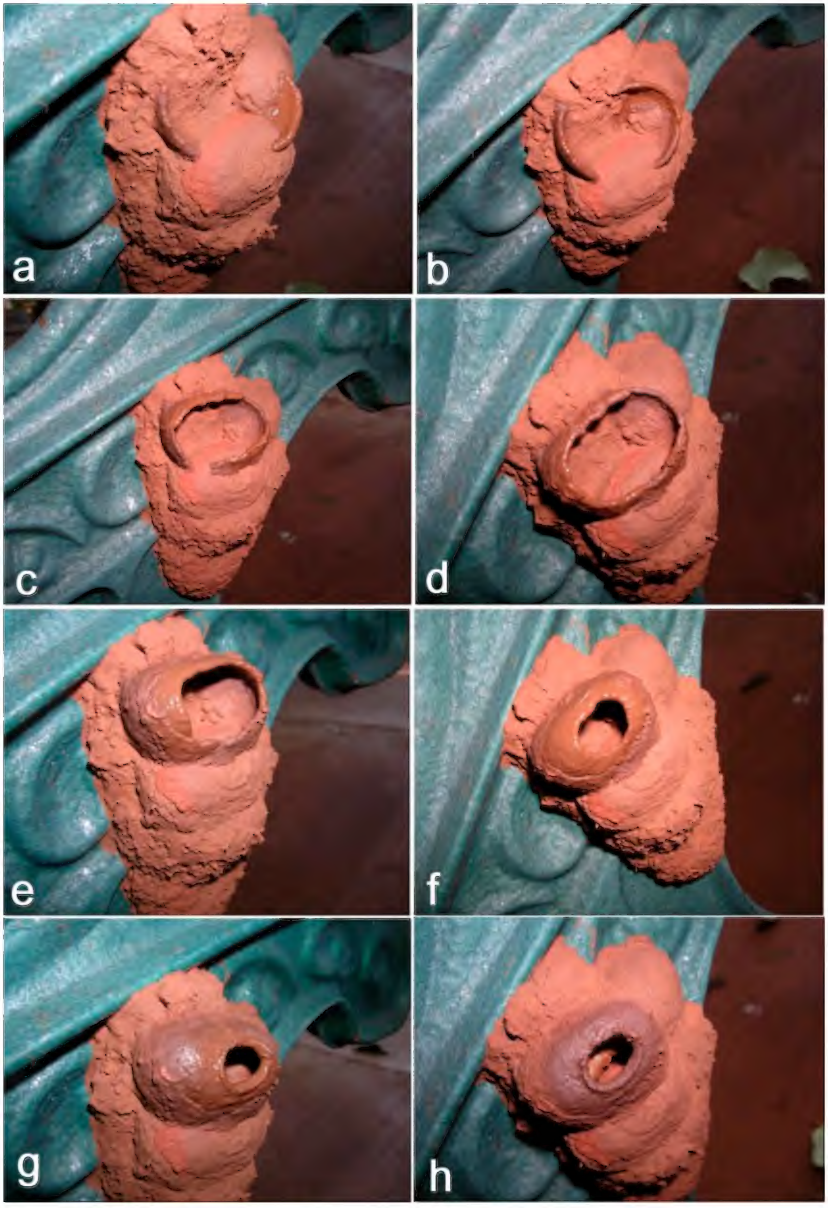


Fig. 4. Stages of cell construction in *D. latreillei*: (a-f) successive placement of mud loads; (g) completed cell with rim just after female finished ovipositing; (h) first prey visible through open entrance where the fresh mud had stretched a bit when the prey were added.

Figs 5-9. (5) *Delta latreillei* female ovipositing into a newly constructed cell; (6) a female of *D. latreillei* inserting prey caterpillar into cell entrance; (7) a chrysidid wasp (*Praestochrysis* sp.) ovipositing into an open and partially provisioned cell of *Delta latreillei*; (8) *Delta latreillei* female performing an inspection visit to the partially provisioned nest; (9) a nest of *Delta latreillei* constructed on a tree branch with the female applying additional mud coating to the exterior.

The number of prey required to fill a cell (and thus the number of hunting forays) almost certainly varies with the season. Late in the dry season when our studies were conducted, the caterpillars were typically 20-40 mm long, generally longer than the wasp (Fig. 6). With prey this large, very few were needed to fill a cell (mean = 3.2 prey, range 2-5, n = 37). One cell's provisioning required only two trips for prey and fewer than 30 minutes of effort. In this instance, the wasp returned with its first prey in just under 15 minutes after oviposition. After inserting it into the cell, the female departed immediately without further inspection or orientation. After 8m55s it returned with a second large caterpillar of apparently the same species and similarly inserted it into the cell opening. Then, before leaving, the wasp briefly inspected the inside of the cell by sticking its head and forelegs into the opening. Upon returning after 1m38s, it carried a load of mud and used it to close the cell opening. On a different occasion, two prey were brought to

the focal cell. After this, the female departed and returned with nothing six times during the ensuing 26 minutes, crawling over the nest each time.

To provision a cell, the female invariably first inserted the caterpillar's head into the cell entrance, then passed its body anteriorly through the wasp's legs. Prey were only very lightly paralysed and responded to our touch by thrashing vigorously. Yamane and Matsuura (1991) reported that some prey of *D. pyriforme* actually completed metamorphosis to the adult within the wasp nest. Prey of *D. latreillei* often continued to defecate after being placed in the nest. Later, when the mature wasp larva spun its cocoon, the (often numerous) caterpillar faecal pellets were invariably separated from the prepupa by a silken wall.

Parasitism

Cuckoo wasps (family Chrysididae) representing three different-sized species (*Stilbum cyanurum* Förster, the largest; medium-sized *Praestochrysis* sp.; and *Chrysis interceptor* Smith, the smallest) were present at the study site and displayed sustained interest in the nest area. (From an isolated nest at another location we also reared *Chrysis festina* Smith). The high intensity of chrysidid parasitism upon *D. latreillei* at our study site was unexpected and we previously had not appreciated the extent to which the three chrysidid species appeared to be competing with one another.

At our focal nests we noted the presence of one or more chrysidids resting nearby at all times, but nesting female *Delta* did not respond to the presence of these parasites on and near the nest. After the provisioning female's departure, we often observed cuckoo wasps visit the nest. On several occasions we saw a chrysidid wasp back its abdomen into the cell entrance, apparently ovipositing (Fig. 7). Naumann (1983) noted that adult chrysidid wasps were common in the vicinity of active nests of *Sceliphron laetum* (Smith) in Kakadu National Park rock art sites, regularly entering cells being actively provisioned when the female was absent. At one of our observation nests, a *Praestochrysis* sp. sat motionless for an extended period while a new nest cell was constructed. However, when the female *Delta* began to bring prey, the cuckoo wasp suddenly became active. It seemed to be clearly waiting for the female to provision, because each time the female delivered another caterpillar and left, the chrysidid immediately flew to the nest and inserted its abdomen into the cell entrance, then returned to the same nearby roosting spot and oriented to face the cell. On other occasions we saw the small chrysidid, *C. interceptor,* disappear completely into open cells during such unattended intervals between provisioning trips.

Between prey trips, *D. latreillei* sometimes returned without prey to partially enter the cell interior. This tendency for females to unpredictably return and begin examining the interior of their current cell, behaviour here termed inspection (Fig. 8), presumably results in the destruction of at least some

parasitoid eggs deposited in their absence. Our impression, however, was that the chrysidid strategy was simply to leave so many eggs that the nesting female would miss one. Observing that some cells of a related *Delta* species, *D. pyriforme,* contained both an egg and a larva, while others contained immature larvae of differing sizes, Yamane and Matsuura (1991) assumed that these indicated usurpation by conspecifics. However, the additional eggs/larvae might have been from chrysidid nest parasites.

Although the chrysidids appeared to monitor nests throughout cell construction, they were never seen to enter cells prior to provisioning, waiting instead until after the first provisioning trip. This suggests the possibility that these chrysidid eggs might be laid on the paralysed caterpillar prey. This location has been noted (Yamane and Matsuura 1991) for an egg found in a *D. pyriforme* nest; not considering the possibility of parasitism, the authors termed it 'anomalous oviposition' by *Delta*.

Although chrysidid wasps were the most common parasites at our study sites, sarcophagid (satellite) flies were also frequent, often trailing females carrying mud or prey. A rhipiphorid beetle (*Macrosiagon* sp.) also has been reared from a *D. latreillei* nest (Callan 1981).

Although we dissected 12 nests, most contained only recently provisioned cells with eggs or young larvae, too early in their development to ascertain the extent of parasitism with any accuracy. However, in one of our focal nests, we found that four of the 14 cells contained chrysidid cocoons, three contained sarcophagid puparia and five had *Delta* larvae or prepupae. (The remaining two cells had been used for experimental manipulations.) Thus, over half (7/12) of the other cells had been parasitised.

In contrast, a completed nest of 18 cells found at the same time – but on the inside of a door inside a nearby building with evidently no other current or old solitary wasp or bee nests in the vicinity – had no parasitised cells; all 18 cells contained viable *Delta* progeny. The previously noted tendency for *D. latreillei* to locate nests in ways that avoid clustering might be an adaptive trait. However, because solitary nesting Hymenoptera are subject to parasitism by a wide range of generalist parasitoids (Krombein 1967), absence of parasitism might be due largely to chance. Nevertheless, susceptibility of *D. latreillei* nests to parasitoid attack no doubt depends in part on their proximity to 'hotspots' with other mud-daubing species' nests.

Outer mud coating behaviour

After cell construction, oviposition, provisioning and cell closure, females made several trips for mud that they applied to the nest exterior in various spots. This initially served to fill in the depressions between adjacent cells and ultimately, in an extended final bout, served to evenly cover the nest surface, resulting in a characteristic dome that obscured the contour of individual cells (see Figs 1-2). The final outer mud coating surface was

coarse, like a rough coat of plaster. This step is not a trivial behaviour – one *Delta* female brought in 96 consecutive mud loads that were applied to the nest exterior. Each trip took about 1.5 minutes (mean = 1m30s, range = 59s-3m14s). During this time chrysidids regularly visited the nest, investigating recent patches or resting motionless within a few centimetres of it. However, they did not directly interact with the *Delta* female.

Response to nest damage

We conducted simple experiments to assess *D. latreillei*'s response to structural damage of nests. Using a small triangular hand file, we cut a short (*ca* 1 cm long) and shallow (*ca* 1 mm deep) transverse groove in the nest surface, while the female was away from the nest continuing to gather coating mud. Upon its return with mud, the wasp immediately applied it to the damaged area and completed the repair using just the single mud load. While the wasp was away, we repeated the experiment on a different part of the nest, with the same result. We next damaged the nest exterior by carving a shallow hole in the surface with a metal spoon handle, again with the same result.

Devoting so much time, energy and attention to the thickness and condition of the nest's exterior suggests that the nest outer coating is particularly important for nest survival. It would be tempting to hypothesise that the mud coating protects the nest from parasitoids and predators. For enemies that oviposit through a nest wall directly into or onto a host, obscuring the exact location of pupae and prepupae would offer a distinct advantage. However, like the chrysidid wasps we observed, other ubiquitous parasitoids would gain far easier access by entering the nest entrance that is left open during provisioning. Enhanced protection against small vertebrate predators such as lizards and birds is also a possibility.

Another hypothesis, not mutually exclusive, is that this outer coating helps waterproof the nest. *Delta latriellei* nests, like nests of other *Delta* species (Yamane and Matsuura 1991), occur in both exposed and sheltered locations and can be oriented both horizontally and vertically (Fig. 9). Northern Australia experiences alternating wet and dry seasons; during the wet season, torrential rains fall. We have noticed that the hemispheric shape of a completed *Delta* nest sheds water efficiently and that nests built on a vertical surface often have a crude 'drip tip' at the basal end (see Fig. 1). It is also possible that the composition of the outer coating mud differs from that used to form the original cells.

Prey acceptance conditions: experimental manipulations

When we observed a *Delta* return to its nest and push back inside a caterpillar that had partially come out, our curiosity was aroused regarding the cues for such behaviour. From cells of another recently completed *Delta* nest, we obtained paralysed prey of the same apparent species for simple experiments.

In our first experiment, three caterpillars were used. One was draped over the top of the cell, another was hung with its head within the cell opening and the third laid about 3 cm below the nest. When the female returned with prey, it landed directly at the cell entrance and, despite its proximity, ignored the extra caterpillar hanging from the hole, knocking it to the ground as the wasp inserted its own prey into the nest. The moment its own caterpillar was inside the nest, however, the wasp rapidly turned and grabbed the caterpillar that was draped across the nest top. Within a few seconds, it was also stuffed into the cell. Then the wasp flew off, ignoring the two prey that lay a few centimetres away below the nest.

For the next experiment, we draped one caterpillar, head upwards, on each side of the cell opening. This time, the female returned without prey and approached the cell entrance as if for an inspection visit. It immediately grabbed one caterpillar head first and stuffed it into the cell. Then it flew off without seeming to notice the second caterpillar.

We then re-hung the surviving caterpillar atop the nest. Returning again without prey, the female immediately attempted to stuff it into the already full nest. After 12 minutes it succeeded, although the caterpillar's body still protruded slightly. The wasp then flew off and shortly returned with a load of mud, using it to close the cell.

As we continued watching, a new cell was initiated almost immediately to the right of the previous one. When it was nearly complete, we decided to determine the female's reaction to having a prey caterpillar on the nest prior to oviposition and before provisioning began. While the female was away, we draped a caterpillar over the nest just above the new cell opening. While the returned female was applying mud to the new cell's lower rim, it noticed the caterpillar, oriented toward it and quickly pushed it off the nest. The wasp then flew off, returning with a final load of mud that it applied to the inside bottom of the cell's rim.

To confirm that a female would accept a prey as its own once provisioning had begun, we next hung a single caterpillar across the top of the cell while the wasp was out searching for its first prey. The female soon returned with a large caterpillar. Rather than flying directly to the nest, it landed a few centimetres away and dragged the prey beneath it. When it got to the nest entrance, the wasp inserted its first prey, then did the same with ours. It took the wasp one minute to insert both caterpillars; then it left.

To test whether the female would take more than one experimentally offered caterpillar, we aligned head-to-tail seven caterpillars in a row along the top of the board to which the nest was attached, with the front half of the first caterpillar above the cell entrance hole. When the female returned, it ignored the displayed caterpillars as it stuffed its own prey into the hole.

While the female was away on its next trip, we similarly positioned the seven prey. This time, the wasp returned without prey, apparently for an inspection. Immediately, it noticed the caterpillar atop the nest and grabbed it, working its way along its body until reaching the dangling head. Then it turned the caterpillar around and pushed it into the cell head first. The wasp paid no attention to the rest of the caterpillars and flew off.

The cell now contained 4 caterpillars, one of which was quite large, and we judged the cell to be full. While the female was away, we placed another caterpillar across the nest above the cell opening as before. When the wasp returned for another inspection, it seized the caterpillar and, with obvious difficulty, eventually pushed it into the cell head first; this required about 10 minutes. We then allowed the wasp to finish closing the cell without further manipulations.

Typically, the act of inserting a caterpillar into the cell appeared to trigger the next step in the 'build, oviposit, hunt, stuff, hunt again' reaction sequence. This could explain why females did not accept more than one displaced prey, even when several extra caterpillars were readily accessible. Random empty-handed returns ('inspection' visits) might serve to monitor potential parasitism as discussed above, but might also serve the non-exclusive additional function of ensuring that the lightly paralysed prey have not crawled out through the cell's opening (or retrieving any that have).

We did not observe instances of prey theft, as reported for other Australian mud-dauber wasps (Matthews and Matthews 2009), but a partially provisioned open cell does offer a potential opportunity that could be adaptively exploited by either conspecifics or other eumenines. Suggestions for further study might include experimental manipulations to determine *D. latreillei*'s response to prey removal from a partly provisioned cell.

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A REVIEW OF THE SUBGENERA *APODACUS* PERKINS, *HEMIZEUGODACUS* HARDY, *NEOZEUGODACUS* MAY, STAT. REV., *SEMICALLANTRA* DREW AND *TETRADACUS* MIYAKE OF *BACTROCERA* MACQUART (DIPTERA: TEPHRITIDAE: DACINAE)

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Abstract

The Indo-Australian subgenera *Apodacus* Perkins (= *Heterodaculus* Hardy, **syn. n.**), *Hemizeugodacus* Hardy, *Neozeugodacus* May, **stat. rev.**, *Semicallantra* Drew and *Tetradacus* Miyake of *Bactrocera* Macquart are reviewed. *Bactrocera* (*Tetradacus*) *superba* Drew & Romig is newly transferred from subgenus *Semicallantra*, *B.* (*Asiadacus*) *fuscans* (Wang) is removed from synonymy with *B.* (*Tetradacus*) *brachycera* (Bezzi) and *B.* (*Bactrocera*) *fuscalata* Drew is transferred from subgenus *Heterodaculus*. The subgeneric placement of *B.* (*Zeugodacus*) *arisanica* (Shiraki) is discussed. Keys to the 23 included species are provided.

Introduction

The five *Bactrocera* Macquart subgenera reviewed here include 22 described plus one undescribed species distributed from India and Japan to Australia and the Solomon Islands. *Apodacus* Perkins (= *Heterodaculus* Hardy, **syn. n.**) and *Semicallantra* Drew are referred to the *Bactrocera* group of subgenera, *Hemizeugodacus* Hardy and *Neozeugodacus* May, **stat. rev.** to the *Melanodacus* group and *Tetradacus* Miyake to a group of its own. A recent list of subgeneric placements for all included species was provided in a Supplementary Table to Doorenweerd *et al*. (2018); not all are followed here.

Genus *Bactrocera* Macquart

Subgenus *Apodacus* Perkins

Apodacus Perkins, 1939: 26. Type species *Apodacus cheesemani* Perkins, 1939 [= *Dacus cheesmanae* Perkins: see Drew, 1989], by original designation.

Dacus (*Heterodaculus)* Hardy, 1951: 134. Type species *Dacus* (*Heterodaculus*) *visendus* Hardy, 1951, by original designation; **syn. n.**

Definition. Abdominal sternite V of male with a deep posterior emargination; posterior lobe of male surstylus short; pecten of cilia present on abdominal tergite III of male; postpronotal setae absent; supra-alar setae present or absent; prescutellar acrostichal setae present or absent; one pair of scutellar setae; ceromata (shining spots) on abdominal tergite V narrow and transverse; scutum with medial postsutural yellow vitta present.

Response to male lures. Methyl eugenol.

Included species. *Bactrocera* (*A*.) *cheesmanae* (Perkins), *B*. (*A*.) *neocheesmanae* Drew and *B*. (*A*.) *visenda* (Hardy).

Host plants. Recorded from the fruit of *Garcinia* spp (Clusiaceae) (Drew 1989, Hancock *et al.* 2000, Novotny *et al*. 2005).

Comments. The combination of a deep emargination to sternite V and short posterior surstylus lobes places this subgenus in the *Bactrocera* group of subgenera as defined by Drew (1989). All species have 3 small frontal setae and a broad transverse fuscous band across the centre of the wing that encloses both crossveins. Antennal scape and pedicel are short (0.15-0.18 and 0.25-0.30 mm respectively). The combination of slit-like ceromata (apomorphy) and a medial yellow vitta on the scutum readily identifies this subgenus and indicates its monophyly.

The included species were previously placed in subgenera *Bactrocera, Polistomimetes* Enderlein or *Heterodaculus* Hardy (Drew 1989, Clarke *et al*. 2004), but were listed under subgenus *Apodacus* by Hancock and Drew (2015). For detailed morphological descriptions and illustrations see Drew (1989). Three species.

B. (*Apodacus*) *cheesmanae* (Perkins)

Apodacus cheesemani Perkins, 1939: 27. Type locality Kokoda, Papua New Guinea.

Dacus (*Apodacus*) *cheesemani* (Perkins); Hardy 1955: 428.

Bactrocera (*Bactrocera*) *cheesmanae* (Perkins); Drew 1989: 126.

Bactrocera (*Apodacus*) *cheesmanae* (Perkins); Hancock *et al*. 2000: 12; Hancock and Drew 2015: 101; Doorenweerd *et al.* 2018: Suppl.

Distribution. Papua New Guinea (Central, East Sepik, Madang, Morobe, Simbu and Western Highlands Provinces: Clarke *et al*. 2004) and one record from Yam Island, Torres Strait, Queensland, Australia (Drew 1989).

Male lure. Methyl eugenol.

Host plant. Garcinia cf. *hollrungii* (Novotny *et al.* 2005).

B. (*Apodacus*) *neocheesmanae* Drew

Bactrocera (*Bactrocera*) *neocheesmanae* Drew, 1989: 147; Doorenweerd *et al.* 2018: Suppl. Type locality Mt Hagen, Western Highlands Province, Papua New Guinea.

Bactrocera (*Apodacus*) *neocheesmanae* Drew; Hancock and Drew 2015: 101.

Distribution. Papua New Guinea (Central, East Sepik, Madang and Western Highlands Provinces: Clarke *et al*. 2004) and West Papua Province, Indonesia (Drew and Romig 2013).

Male lure. Methyl eugenol.

Host plants. Garcinia cf. *hollrungii* and *G. ledermannii* (Novotny *et al.* 2005). A record from *Atractocarpus macarthurii* (Rubiaceae) (Novotny *et al.* 2005) is doubtful and likely resulted from a sampling error.

B. (*Apodacus*) *visenda* (Hardy)

Dacus (*Heterodaculus*) *visendus* Hardy, 1951: 134. Type locality Babinda, Queensland, Australia.

Daculus visendus (Hardy); May 1963: 40, 49.

Dacus (*Daculus*) *visendus* (Hardy); Drew 1974: 10.

Dacus (*Polistomimetes*) *visendus* (Hardy); Drew 1979: 96.

Bactrocera (*Polistomimetes*) *visenda* (Hardy); Drew 1989: 176.

Bactrocera (*Heterodaculus*) *visenda* (Hardy); Norrbom *et al.* 1999: 98.

Bactrocera (*Apodacus*) *visenda* (Hardy): Hancock *et al*. 2000: 12; Hancock and Drew 2015: 101; Doorenweerd *et al.* 2018: Suppl.

Distribution. Southern Papua New Guinea (Central, Gulf, Morobe and Western Provinces: Clarke *et al*. 2004), Torres Strait islands and eastern Queensland, Australia as far south as the Tully district (Hancock *et al*. 2000).

Male lure. Methyl eugenol.

Host plants. Garcinia warrenii and possibly *G. gibbsiae* (Hancock *et al*. 2000).

Comments. The host plant and seasonal abundance of this species were discussed by Royer and Dostie (2004).

Key to *Apodacus* species

1 Scutum red-brown; supra-alar and prescutellar acrostichal setae absent ..... *B*. (*A*.) *visenda* (Hardy)

– Scutum mostly fuscous to black; supra-alar and prescutellar acrostichal setae present 2

2 Abdominal tergites III-V broadly fuscous laterally .... *B*. (*A*.) *cheesmanae* (Perkins)

– Abdominal tergites III-V at most very narrowly fuscous laterally .... *B*. (*A*.) *neocheesmanae* Drew

Subgenus *Hemizeugodacus* Hardy

Dacus (*Hemizeugodacus*) Hardy, 1951: 131. Type species *Dacus aglaiae* Hardy, 1951, by original designation.

Definition. Abdominal sternite V of male with a shallow posterior emargination; posterior lobe of male surstylus short and blunt; pecten of cilia present on abdominal tergite III of male; postpronotal setae absent; supra-alar setae present; prescutellar acrostichal setae present; two pairs of scutellar setae; scutum with medial postsutural yellow vitta present.

Response to male lures. Cue lure (1 species), zingerone (1 species) or unknown (1 species).

Included species. *Bactrocera* (*H*.) *aglaiae* (Hardy), *B*. (*H*.) *fulvosterna* Drew & Romig and *B*. (*H*.) *tetrachaeta* (Bezzi).

Host plants. *Aglaia* spp (Meliaceae) or unknown.

Comments. *Hemizeugodacus* differs from other *Melanodacus* group subgenera in having the medial postsutural yellow vitta present and 2 pairs of scutellar setae.

Included species

B. (*Hemizeugodacus*) *aglaiae* (Hardy)

Dacus (*Hemizeugodacus*) *algaiae* Hardy, 1951: 132. Type locality Atherton Tableland, Queensland, Australia. Emended to *aglaiae* by Hardy 1952: 365.

Neozeugodacus aglaiae (Hardy); May 1963: 50.

Bactrocera (*Hemizeugodacus*) *aglaiae* (Hardy); Drew 1989: 178.

Distribution. NE Queensland (Lockhart River and Portland Roads, Atherton Tableland and Mossman to Tully) (Drew 1989, Hancock *et al*. 2000, Royer 2015) and eastern Indonesia (Papua Province) (White and Evenhuis 1999).

Male lure. Zingerone (Royer 2015).

Host plants. *Aglaia sapindina* and *A. ferruginea* (Meliaceae) (Hardy 1951, Hancock *et al.* 2000).

Comments. Illustrated by Drew (1989). A record of '*Zeugodacus atrisetosus*' bred from '*Hearnia*' [now *Aglaia*] *sapindina* in northern Queensland (Perkins and May 1949) actually refers to *B*. (*H*.) *aglaiae*.

B. (*Hemizeugodacus*) *fulvosterna* Drew & Romig

Bactrocera (*Parazeugodacus*) *fulvosterna* Drew & Romig, 2013: 245. Type locality Gunung Mulu National Park, Sarawak, East Malaysia.

Bactrocera (*Hemizeugodacus*) *fulvosterna* Drew & Romig; Hancock and Drew 2015: 95; Doorenweerd *et al.* 2018: Suppl.

Distribution. Sarawak, East Malaysia.

Male lure. Cue lure (Drew and Romig 2013).

Host plants. None known.

Comments. Illustrated by Drew and Romig (2013).

B. (*Hemizeugodacus*) *tetrachaeta* (Bezzi)

Chaetodacus tetrachaetus Bezzi, 1919: 431. Type locality Batbatan I., Philippines.

Dacus (*Zeugodacus*) *tetrachaetus* (Bezzi), Hardy and Adachi 1954: 196.

Dacus (*Zeugodacus*) *deceptus* Hardy, 1974: 46. Type locality 11 km E of Sindangan, Zamboanga del Norte, Mindanao, Philippines. Syn. Drew and Romig 2013: 248.

Bactrocera (*Zeugodacus*) *tetrachaeta* (Bezzi), Norrbom *et al*. 1999: 104.

Bactrocera (*Parazeugodacus*) *tetrachaeta* (Bezzi), Drew and Romig 2013: 248.

Bactrocera (*Hemizeugodacus*) *tetrachaeta* (Bezzi); Hancock and Drew 2015: 95; Doorenweerd *et al.* 2018: Suppl.

Distribution. Philippines (Batbatan and Mindanao) (Drew and Romig 2013).

Male lure. None known.

Host plants. None known.

Comments. Illustrated by Drew and Romig (2013).

Species excluded from *Hemizeugodacus*

B. (*Zeugodacus*) *arisanica* (Shiraki)

Zeugodacus arisanicus Shiraki, 1933: 31. Type locality Arisan, Taiwan.

Dacus (*Zeugodacus*) *arisanica* (Shiraki); Tseng *et al.* 1992: 58.

Dacus (*Zeugodacus*) *parvifoliaceus* Tseng, Chen & Chu, 1992: 71. Type locality Nantou, Yilan Hsien, Taiwan. Syn. Drew and Romig 2013: 244.

Bactrocera (*Zeugodacus*) *arisanica* (Shiraki); Norrbom *et al*. 1999: 102.

Bactrocera (Parazeugodacus) *arisanica* (Shiraki); Drew and Romig 2013: 244.

Bactrocera (*Hemizeugodacus*) *arisanica* (Shiraki); Hancock and Drew 2015: 95.

Zeugodacus (*Hemizeugodacus*) *arisanicus* Shiraki; Doorenweerd *et al.* 2018: Suppl.

Distribution. Taiwan and Thailand (Drew and Romig 2013). Recorded from 600-2500 m in Taiwan (Tseng *et al*. 1992).

Male lure. Cue lure (Tseng *et al*. 1992, Drew and Romig 2013).

Host plants. None known.

Comments. Illustrated by Drew and Romig (2013) and Tseng *et al*. (1992). This species was returned to 'genus' *Zeugodacus* Hendel by Doorenweerd *et al*. (2018) on the basis of the presence of a postsutural medial yellow vitta, presutural extensions to the postsutural lateral yellow vittae and molecular evidence. The two character states also occur within other subgenera in the *Bactrocera* and *Melanodacus* groups (*e.g. Bulladacus* Drew & Hancock, *Bactrocera s.s*. and *Notodacus* Perkins) and thus are not definitive indicators of a *Zeugodacus* placement. However, a molecular study by San Jose *et al.* (2018) found strong support for including it in a clade with *B*. (*Z*.) *aithonata* Drew & Romig, *B*. ('*Javadacus*') *trilineata* (Hardy), *B*. ('*Hemigymnodacus*') *mukiae* Drew & Romig and *B*. (*Z*.) *tappanus* (Shiraki). These species are morphologically similar and we regard the reduced posterior surstylus lobes of *B*. (*Z*.) *arisanica*, short but still directed posteroventrally as in other *Zeugodacus* group species (see Tseng *et al*. 1992), as an apomorphy. The molecularly indicated *Dacus-Zeugodacus* sister relationship is not strongly supported (*e.g*. San Jose *et al*. 2018) and no synapomorphy linking them has been identified. We therefore continue to regard *Zeugodacus* as a subgenus within *Bactrocera*, placing more reliance on an observable synapomorphy, the frequent presence of prescutellar acrostichal and/or basal scutellar setae in all *Bactrocera* groups of subgenera, including *Tetradacus*. These setae have not been recorded in *Dacus* Fabricius or the primitive dacine genera *Ichneumonopsis* Hardy and *Monacrostichus* Bezzi.

Subgenus *Neozeugodacus* May, stat. rev.

Neozeugodacus May, 1952: 10. Type species *Neozeugodacus aureus* May, 1952, by original designation.

Definition. Abdominal sternite V of male with a shallow posterior emargination; posterior lobe of male surstylus short; pecten of cilia present

on abdominal tergite III of male; postpronotal setae absent; supra-alar setae present or absent; prescutellar acrostichal setae present; one or two pairs of scutellar setae; scutum with medial postsutural yellow vitta absent.

Response to male lures. Cue lure (1 species), zingerone (1 species) or unknown (2 species).

Included species. *Bactrocera* (*N.*) *abdomininigra* Drew, *B.* (*N.*) *aurea* (May), *B.* (*N.*) *buinensis* Drew and *B.* (*N.*) *ektoalangiae* Drew & Hancock.

Host plants. *Alangium villosum* subspp (Alangiaceae) or unknown.

Comments. *Neozeugodacus* differs from other *Melanodacus* group subgenera in the combination of medial postsutural yellow vitta absent (separating it from *Hemizeugodacus* Hardy), pecten on abdominal tergite III present in males, anatergite mostly yellow and wing with a distinct anal stripe.

B. (*Neozeugodacus*) *abdomininigra* Drew

Bactrocera (*Hemizeugodacus*) *abdomininigra* Drew, 1989: 179. Type locality Naibata Banda logging area, Bulolo, Papua New Guinea.

Distribution. Papua New Guinea (Morobe Province).

Male lure. None known.

Host plants. None known.

Comments. Illustrated by Drew (1989).

B. (*Neozeugodacus*) *aurea* (May)

Neozeugodacus aureus May, 1952: 10. Type locality Ravensbourne, SE Queensland, Australia.

Bactrocera (*Hemizeugodacus*) *aurea* (May); Drew 1989: 181.

Distribution. Northeastern (Lockhart River) and southeastern Queensland (Royer 2015).

Male lure. Zingerone (Royer 2015).

Host plant. Alangium villosum subsp. *tomentosum* (Alangiaceae) (Hancock *et. al*. 2000).

Comments. Supra-alar setae are absent and the basal scutellar setae are weakly developed. Illustrated by Drew (1989) and May (1952).

B. (*Neozeugodacus*) *buinensis* Drew

Bactrocera (*Bactrocera*) *buinensis* Drew, 1989: 123. Type locality Buin, Bougainville, Papua New Guinea.

Bactrocera (*Hemizeugodacus*) *buinensis* Drew; Drew and Romig 2001: 141.

Distribution. Papua New Guinea (Bougainville) and Solomon Islands (Kolombangara and Choiseul) (Drew and Romig 2001).

Male lure. Cue lure (Drew and Romig 2001).

Host plants. None known.

Comments. Only one pair of scutellar setae, the basal pair absent. Illustrated by Drew (1989) and Drew and Romig (2001).

B. (*Neozeugodacus*) *ektoalangiae* Drew & Hancock

Bactrocera (*Hemizeugodacus*) *ektoalangiae* Drew & Hancock in Drew *et al*., 1999: 9. Type locality 3.5 km along Goldsborough Valley [nr Gordonvale], Queensland, Australia.

Distribution. Northern Queensland (Cairns district).

Male lure. None known.

Host plant. *Alangium villosum* subsp. *polyosmoides* (Alangiaceae) (Drew *et al*. 1999).

Comments. Only one pair of scutellar setae, the basal pair absent. Illustrated by Drew *et al*. (1999).

Key to species of *Hemizeugodacus* and *Neozeugodacus*

Combined due to previous placement of all species in *Hemizeugodacus*.

1 Scutum with medial postsutural yellow vitta present .... subgenus *Hemizeugodacus* Hardy ... 2

– Scutum with medial postsutural yellow vitta absent .... subgenus *Neozeugodacus* May ... 4

2 Wing with crossvein DM-Cu and apex of vein Cu_1 infuscated; scutellum with a small black apical spot ..... *B.* (*H.*) *fulvosterna* Drew & Romig

– Wing with crossvein DM-Cu and apex of vein Cu_1 not infuscated; scutellum without an apical black spot 3

3 Scutum largely black with lateral presutural yellow vittae reaching postpronotal lobes; wing with anal streak absent; abdomen with a broad black medial vitta and lateral margins connected along base of tergite III ..... *B.* (*H.*) *tetrachaeta* (Bezzi)

– Scutum red-brown without lateral presutural yellow vittae; wing with anal streak distinct; abdomen fulvous with at most a faint indication of a narrow medial vitta and lateral margins ..... *B.* (*H.*) *aglaiae* (Hardy)

4 Scutum black without postsutural lateral yellow vittae; postpronotal lobes black; legs with mid and hind femora apically black; abdomen almost entirely black ..... *B.* (*N.*) *abdominingra* Drew

– Scutum fulvous to red-brown with postsutural lateral yellow vittae present; postpronotal lobes yellow; legs with all femora fulvous; abdomen largely fulvous to red-brown with a medial black vitta and often with darker lateral margins 6

5 Wing with a pale fuscous transverse medial band covering both crossveins; supra-alar setae absent; 2 pairs of scutellar setae, the basal pair weak ..... *B.* (*N.*) *aurea* (May)

– Wing without a fuscous transverse medial band covering both crossveins; supra-alar setae present; 1 pair of scutellar setae, the basal pair absent ... 7

6 Scutum with postsutural lateral yellow vittae ending before intra-alar setae; scutellum with a broad red-brown to fuscous medial vitta; abdomen red-brown with a medial black vitta over all or some tergites III-V .... *B.* (*N.*) *buinensis* Drew

– Scutum with postsutural lateral yellow vittae reaching intra-alar setae; scutellum without a broad dark medial vitta; abdomen with a medial black vitta and broad black lateral margins over tergites III-V .... *B.* (*N.*) *ektoalangiae* Drew & Hancock

Subgenus *Semicallantra* Drew

Dacus (*Semicallantra*) Drew, 1989: 17. Type species *Dacus* (*Semicallantra*) *aquilus* Drew, 1989, by original designation.

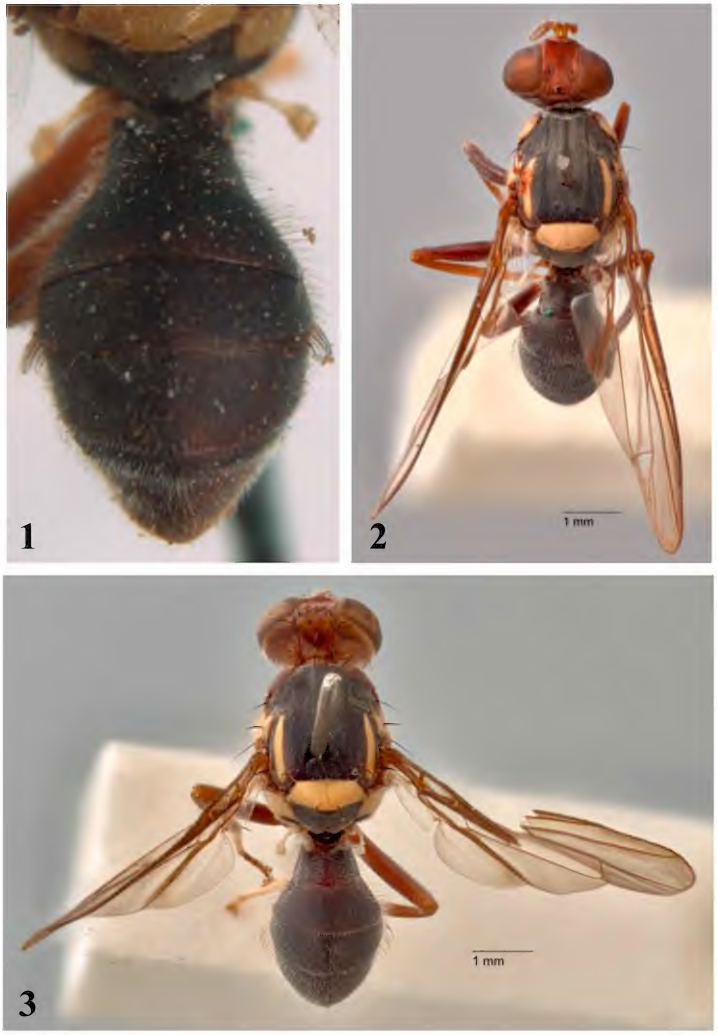
Definition. Abdominal sternite V of male with a deep posterior emargination; posterior lobe of male surstylus short to moderately produced; pecten of cilia present on abdominal tergite III of male; antennal scape and pedicel elongate; postpronotal setae absent; supra-alar setae absent; prescutellar acrostichal setae present or absent; one pair of scutellar setae; ceromata (shining spots) on abdominal tergite V large and rounded; scutum with medial postsutural yellow vitta absent and lateral postsutural vittae, when present, narrowing anteriorly.

Response to male lures. Cue lure, methyl eugenol (error?) or not recorded.

Included species. *Bactrocera* (*S.*) *aquila* (Drew), *B.* (*S.*) *incompta* Drew & Romig, *B.* (*S.*) *memnonia* (Drew), *B.* (*S.*) *nigricula* (Drew) and *B.* (*S.*) *toxopeusi* (Hering).

Host plants. None recorded.

Comments. The combination of a deep emargination to sternite V and short posterior surstylus lobes places this subgenus in the *Bactrocera* group of subgenera as defined by Drew and Romig (2013). All species have subpetiolate and elongate-oval abdomens of varying width (*e.g.* Fig. 1), 2 small frontal setae and the antennal scape and pedicel relatively elongate (0.30-0.37 and 0.39-0.51 mm respectively). The scape and pedicel are distinctly longer than usual in *Bactrocera* (homoplasious apomorphy) and the postsutural lateral yellow vittae on the scutum, when present, are narrower anteriorly than posteriorly (apomorphy); these two characters indicate monophyly for the subgenus. With the exception of *B. toxopeusi*, all species were included in *Semicallantra* by Doorenweerd *et al.* (2018).



Figs 1-3. *Bactrocera* (*Semicallantra*) spp: (1) *B. toxopeusi* (Hering), abdomen of holotype male; (2) *B. aquila* (Drew), holotype male; (3) *B. nigricula* (Drew), holotype male. Photo (1) by Pasquale Ciliberti © Museum Naturalis, Leiden; photos (2-3) by Geoff Thompson © Queensland Museum.

This subgenus was transferred from *Dacus* Fabricius to the *Bactrocera* group of subgenera by Drew and Hancock (1999) and its then included species were listed by Clarke *et al*. (2004). A sixth previously included species, *B. superba* Drew & Romig (Drew and Romig 2013, 2016), left unplaced by Hancock and Drew (2015), is transferred here to subgenus *Tetradacus* (see below).

For detailed morphological descriptions and illustrations of all included species see Drew (1974, 1989) and Drew and Romig (2013). Five species.

B. (*Semicallantra*) *aquila* (Drew) (Fig. 2)

Dacus (*Semicallantra*) *aquilus* Drew, 1989: 264. Type locality Mt Kaindi, Morobe Province, Papua New Guinea.

Bactrocera (*Semicallantra*) *aquila (*Drew); Clarke *et al*. 2004: 155.

Distribution. Papua New Guinea (Madang and Morobe Provinces: Clarke *et al*. 2004).

Male lure. Cue lure.

Host plants. None recorded.

B. (*Semicallantra*) *incompta* Drew & Romig

Bactrocera (*Semicallantra*) *incompta* Drew & Romig, 2013: 249. Type locality Waai, Ambon Island, Maluku, Indonesia.

Distribution. Eastern Indonesia (Ambon).

Male lure. Cue lure.

Host plants. None recorded.

Comments. The abdomen is narrower and more elongate than in mainland New Guinea species.

B. (*Semicallantra*) *memnonia* (Drew)

Dacus (*Semicallantra*) *memnonius* Drew, 1989: 265. Type locality Hombrom Bluff, Central Province, Papua New Guinea.

Bactrocera (*Semicallantra*) *memnonia* (Drew); Clarke *et al*. 2004: 155.

Distribution. Papua New Guinea (Central, East Sepik and Oro (Northern) Provinces: Clarke *et al*. 2004).

Male lure. The holotype was collected at methyl eugenol but other subgeneric records are from cue lure and this record requires confirmation.

Host plants. None recorded.

B. (*Semicallantra*) *nigricula* (Drew) (Fig. 3)

Dacus (*Semicallantra*) *nigriculus* Drew, 1989: 266. Type locality Robbies Creek, Stony logging area [nr Bulolo], Morobe Province, Papua New Guinea.

Bactrocera (*Semicallantra*) *nigricula* (Drew); Clarke *et al*. 2004: 155.

Distribution. Papua New Guinea (Morobe Province).

Male lure. Not recorded; the holotype and only known specimen was hand collected underneath a *Musa* leaf.

Host plants. None recorded.

B. (*Semicallantra*) *toxopeusi* (Hering)

Daculus toxopeusi Hering, 1953: 510. Type locality Hollandia [=Jayapura], Papua Province, Indonesia.

Dacus (*Daculus*) *toxopeusi* (Hering); Drew 1974: 8.

Bactrocera (*Polistomimetes*) *toxopeusi* (Hering); Drew 1989: 176.

Bactrocera (*Heterodaculus*) *toxopeusi* (Hering); Norrbom *et al.* 1999: 98; Doorenweerd *et al*. 2018: Suppl.

Bactrocera (*Semicallantra*) *toxopeusi* (Hering); Hancock and Drew 2015: 101.

Distribution. Eastern Indonesia (northern Papua Province).

Male lure. Not recorded; known only from the holotype male.

Host plants. None recorded.

Comments. This species differs from the others in lacking prescutellar acrostichal setae. The shape and coloration of the abdomen (Fig. 1) are as in *B. nigricula* and the two are possibly synonymous.

Key to *Semicallantra* species

1 Abdominal tergites mostly or entirely orange-brown; postsutural lateral yellow vittae absent; postpronotal and notopleural lobes both fuscous ..... *B.* (*S.*) *incompta* Drew & Romig

– Abdominal tergites almost or entirely fuscous to black; postsutural lateral yellow vittae present or absent; postpronotal lobe black or mostly yellow; notopleural lobe at least partly yellow 2

2 Postpronotal lobe yellow with a black anterior margin; notopleural lobe black basally, yellow at apex; postsutural lateral yellow vittae very weakly tapered anteriorly ..... *B.* (*S.*) *aquila* (Drew)

– Postpronotal lobe black; notopleural lobe yellow; postsutural lateral yellow vittae distinctly tapered anteriorly or absent 3

3 Scutum black without postsutural lateral yellow vittae .... *B.* (*S.*) *memnonia* (Drew)

– Scutum black with postsutural lateral yellow vittae that taper anteriorly 4

4 Prescutellar acrostichal setae absent; fore and mid tibiae fulvous .... *B.* (*S.*) *toxopeusi* (Hering)

– Prescutellar acrostichal setae present; fore and mid tibiae dark red-brown to fuscous ..... *B.* (*S.*) *nigricula* (Drew)

Subgenus *Tetradacus* Miyake

Dacus (*Tetradacus*) Miyake, 1919: 92. Type species *Dacus tsuneonis* Miyake, 1919, by original designation.

Polistomimetes Enderlein, 1920: 358. Type species *Polistomimetes minax* Enderlein, 1920, by original designation. Syn. White and Wang 1992: 276.

Definition. Abdominal sternite V of male with a shallow (slight to moderate) posterior emargination; posterior lobe of male surstylus short; pecten of cilia present on abdominal tergite III of male; postpronotal seta absent; supra-alar setae present or absent; prescutellar acrostichal setae present or absent; one pair of scutellar setae; scutum with medial postsutural yellow vitta usually present; female oviscape usually bulbous, rounded in cross-section.

Response to male lures. Cue lure (1 species), zingerone (1 species) or unknown.

Included species. *Bactrocera brachycera* (Bezzi), *B. mesonotochra* Drew (= *B. neopagdeni* Drew, **syn. n.**), *B. minax* (Enderlein), *B. pagdeni* (Malloch), *B. splendida* (Perkins), *B. superba* Drew & Romig and *B. tsuneonis* (Miyake).

Host plants. Two species recorded from the fruit of Rutaceae; others unknown (White and Wang 1992, Drew and Romig 2013).

Comments. The shallow emargination to sternite V and short posterior surstylus lobe in males distinguish this subgenus from both the *Zeugodacus* (with a long posterior surstylus lobe) and *Bactrocera* (with a deeply emarginate sternite V) groups of subgenera as defined by Drew (1989). In these sternite V and surstylus lobe characters it resembles the *Melanodacus* group of subgenera, differing from most subgenera in that group in the presence of a postsutural medial yellow vitta and only one pair (apical) of scutellar setae, from *Notodacus* Perkins spp in the non-bilobed scutellum and lack of a postpronotal seta, and from *Hemizeugodacus* spp that lack both a postsutural medial yellow vitta and basal scutellar setae, in having a costal band that broadly reaches vein M at least over its apical section. Where known, in all but one species the female oviscape is bulbous and rounded in cross-section, unlike the oval or flattened shape normally seen in *Bactrocera*. The species are generally large (wing length 6.2-10.8 mm).

Included species

Tetradacus is considered here to contain seven described and one undescribed species distributed from India and Japan to the Solomon Islands, with one newly transferred from subgenus *Semicallantra* Drew and one newly synonymised. *Bactrocera (Asiadacus) fuscans* (Wang), previously placed as a synonym of *B. brachycera* (Bezzi), is removed from synonymy on morphological grounds. Two included species, *B. minax* (Enderlein) and *B. tsuneonis* (Miyake), are regarded as economically important pests of *Citrus* and *Fortunella* (Rutaceae) in eastern Asia.

For detailed morphological descriptions and illustrations of all described species see Drew (1989) and Drew and Romig (2013). An additional, undescribed species is known from a single male from 'New Guinea'. Two species-groups are recognisable, based on the presence or absence of a patch of dense microtrichia at the end of vein A_1+CuA_2 in males (absent in all females) and geographical distribution.

Group A: Wing with costal cells bc and c not entirely or largely covered with dense microtrichia and, in males, without a patch of dense microtrichia at the end of vein A_1+CuA_2; abdomen with a dark medial vitta. Japan and China to northern India. Three species.

B. (*Tetradacus*) *brachycera* (Bezzi)

Mellesis brachycera Bezzi, 1916: 116. Type locality Bhimtal Kumtal, Uttar Pradesh, India.

Bactrocera (*Tetradacus*) *brachycera* (Bezzi): Norrbom *et al.* 1999: 101; Drew and Romig 2013: 259; Doorenweerd *et al.* 2018: Suppl.

Distribution. Northern India (Uttar Pradesh, Uttarakhand) and Bhutan (Drew and Romig 2013).

Male lure. None known.

Host plant. None known.

Comments. This species differs from others included in *Tetradacus* in the combination of a short, non-bulbous and dorsoventrally flattened oviscape and lack of a postsutural medial yellow vitta on the scutum. It most resembles species in subgenus *Sinodacus* Zia but has short posterior surstylus lobes and is best retained in *Tetradacus*. However, the previously included synonym *B. fuscans* (Wang) is excluded from *Tetradacus* – see below.

B. (*Tetradacus*) *minax* (Enderlein)

Polistomimetes minax Enderlein, 1920: 358. Type locality Sikkim, India.

Mellesis citri Chen, 1940: 133. Type locality Chengdu, Sichuan, China. Syn. White and Wang 1992: 276.

Bactrocera (*Tetradacus*) *minax* (Enderlein): White and Wang 1992: 276.

Distribution. Southern China (Guangxi, Guizhou, west Hubei, west Hunan, Jiangsu [Donghai County], southern Shaanxi, Sichuan, Yunnan), Nepal, Bhutan and NE India (Sikkim, West Bengal) (Yang 1988, 1991, White and Wang 1992, Wang 1998, Drew and Romig 2013).

Male lure. None known. The weak attraction of both sexes to methyl eugenol during May-July 2000 in Bhutan (Drew *et al.* 2007) appears to be a result of other factors, such as chance or the trap itself (*e.g.* colour, positioning or other contents).

Host plants. Citrus and *Fortunella* spp (Rutaceae) (White and Wang 1992, Wang 1998, Allwood *et al*. 1999).

Comments. This species is regarded as a serious economic pest. There is some uncertainty over the Jiangsu record: it is likely that records of both '*B. citri*' and '*B. cheni*' from the isolated Donghai County (Yang 1988) refer to a single species, misidentified as '*B. citri*' (= *B. minax*) before being included in the type series of '*B. cheni*' (= *B. tsuneonis*).

B. (*Tetradacus*) *tsuneonis* (Miyake)

Dacus (*Tetradacus*) *tsuneonis* Miyake, 1919: 92. Type locality Tsugumi, Kyushu, Japan.

Dacus (*Tetradacus*) *cheni* Chao, 1987: 4. Type locality Pingxiang, Guangxi, China. Syn. White and Wang 1992: 277.

Bactrocera (*Tetradacus*) *tsuneonis* (Miyake): White and Wang 1992: 277.

Distribution. Southern Japan (Kyushu, Amamioshima) and southern China (Guangxi, Guizhou, west Hunan, Jiangsu [Donghai County], Sichuan) (Yang 1988, White and Wang 1992, Wang 1998). Records from Taiwan appear to be in error (Tseng *et al*. 1992).

Male lure. None known.

Host plants. Citrus and *Fortunella* spp (Rutaceae) (White and Wang 1992, Wang 1998, Allwood *et al*. 1999).

Comments. This species is regarded as a serious economic pest. Supra-alar setae are present and often doubled on one or both sides (White and Wang 1992). White and Wang (1992) recorded paratypes of '*B. cheni'* from both Hunan and Jiangsu Provinces but Wang (1998) noted that these records required confirmation (but see Comments under *B. minax*).

Group B: Wing with costal cell c entirely and cell bc at least partly covered with dense microtrichia and, in males, with a patch of dense microtrichia at the end of vein A_1+CuA_2; abdomen without a dark medial vitta. Indonesia, Papua New Guinea and Solomon Islands. Five species.

B. (*Tetradacus*) *mesonotochra* Drew

Bactrocera (*Polistomimetes*) *mesonotochra* Drew, 1989: 172. Type locality Bubia nr Lae, Morobe Province, Papua New Guinea.

Bactrocera (*Polistomimetes*) *neopagdeni* Drew, 1989: 175. Type locality 20 km SE of Port Moresby, Central Province, Papua New Guinea. **Syn. n.**

Bactrocera (*Tetradacus*) *neopagdeni* Drew: White and Wang 1992: 276.

Bactrocera (*Heterodaculus*) *mesonotochra* Drew: Norrbom *et al*. 1999: 98; Clarke *et al*. 2004: 155; Doorenweerd *et al.* 2018: Suppl.

Bactrocera (*Tetradacus*) *mesonotochra* Drew: Hancock and Drew 2015: 101.

Distribution. Papua New Guinea (Central and Morobe Provinces).

Male lure. None known.

Host plant. None known.

Comments. The sexes of this species (*B. mesonotochra* male and *B. neopagdeni* female) differ from each other in exactly the same way as those of *B. pagdeni* (see below) and are thus considered synonymous, with nomenclatural priority given to the first described *B. mesonotochra*.

B. (*Tetradacus*) *pagdeni* (Malloch)

(Figs 4-6)

Dacus pagdeni Malloch, 1939: 243. Type locality Tulagi Ridge, Florida I., Solomon Islands.

Bactrocera (*Polistomimetes*) *pagdeni* (Malloch): Drew 1989: 176.

Bactrocera (*Tetradacus*) *pagdeni* (Malloch): White and Wang 1992: 276; Drew and Romig 2001: 145.

Distribution. Solomon Islands (Florida and Guadalcanal Is).

Male lure. Zingerone.

Host plant. None known.

Comments. Newly recorded males (Figs 4-6) from Guadalcanal (Numbu, Honiara, Henderson (Kobol) and Obobo Village: in Department of Agriculture and Water Resources Collection, Cairns), collected by Luke Halling at zingerone lure in April-May 2017, differ from the female in having the abdomen narrower and largely fulvous with black lateral margins and ceromata (shining spots on tergite V).

B. (*Tetradacus*) *splendida* (Perkins)

Callantra splendida Perkins, 1938: 136. Type locality Preanger Djampang Tenggah, West Java, Indonesia.

*Bactrocera splendida (*Perkins): White and Wang 1992: 278.

Bactrocera (*Tetradacus*) *splendida* (Perkins): Norrbom *et al*. 1999: 101; Drew and Romig 2013: 261.

Distribution. Indonesia (West Java).

Male lure. None known.

Host plant. None known.

Comments. Despite the unusually elongate antennal scape and pedicel, the shape of the female oviscape is consistent with most other species included in *Tetradacus* and it appears to be correctly placed in this subgenus.

B. (*Tetradacus*) *superba* Drew & Romig

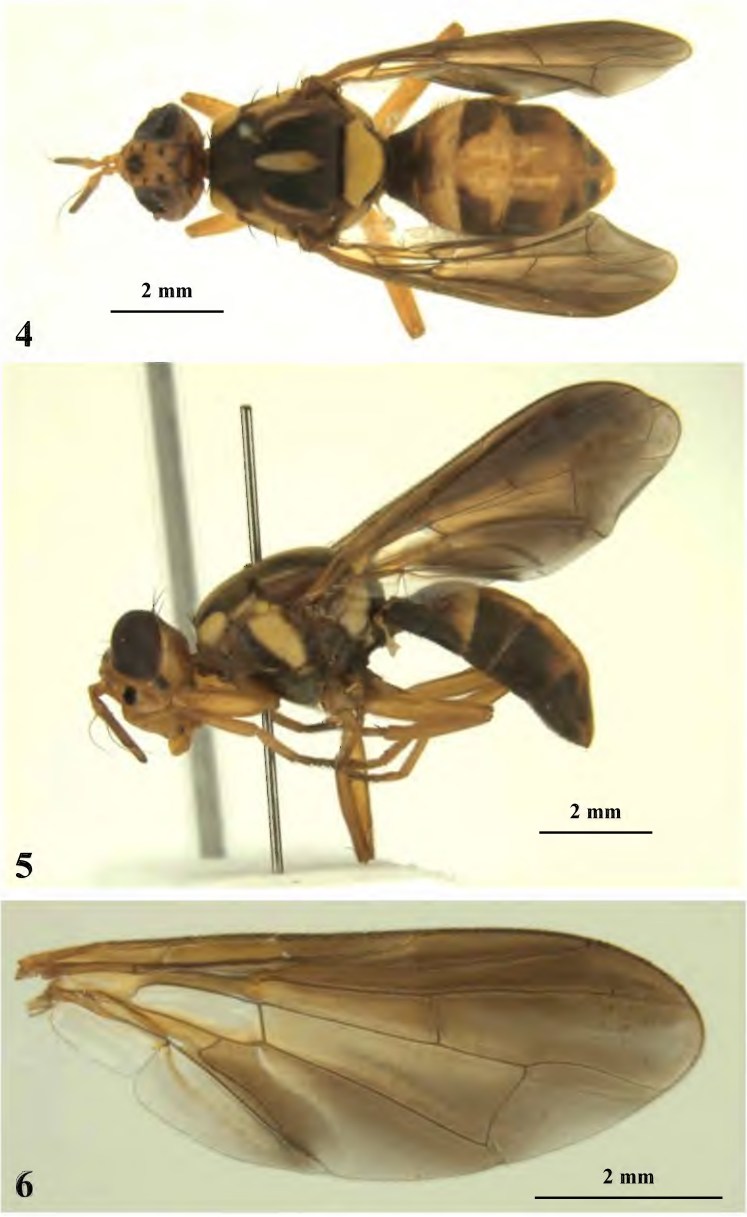
(Fig. 7)

Bactrocera (*Semicallantra*) *superba* Drew & Romig, 2013: 250; Doorenweerd *et al.* 2018: Suppl. Type locality Goal, West Halmahera, Maluku, Indonesia.

Distribution. Eastern Indonesia (Halmahera, northern Maluku).

Male lure. Cue lure (Drew and Romig 2013).

Host plant. None known.



Figs 4-6. *Bactrocera* (*Tetradacus*) *pagdeni* (Malloch), males from Guadalcanal: (4) dorsal view; (5) lateral view; (6) wing. Photos by David Britton (Department of Agriculture and Water Resources, Cairns).

Figs 7-9. *Bactrocera* (*Tetradacus*) spp: (7) *B. superba* Drew & Romig, paratype male; (8-9) *B.* (*Tetradacus*) undescribed male (barcode number BMNH(E) 1440325) from West Papua, Indonesia: (8) dorsal view; (9) wing. Photo (7) by Geoff Thompson © Queensland Museum, Brisbane; photos (8-9) by Daniel Whitmore © Trustees of the Natural History Museum, London.

Comments. This species has a shallow emargination to sternite V and short posterior surstylus lobes, this combination thus excluding it from the *Bactrocera* group of subgenera and placing it in either *Tetradacus* or the *Melanodacus* group of subgenera. A trace of a postsutural medial yellow vitta is present in an examined paratype (Fig. 4). Left unplaced by Hancock and Drew (2015), its large size and the shape of the abdomen suggest an affinity with *Tetradacus* and it is provisionally referred to this subgenus. It differs from other *Tetradacus* species in having both supra-alar and prescutellar acrostichal setae weakly present [although supra-alar setae are present also in *B*. (*T*.) *tsuneonis*]. The female has not been recorded and the shape of the oviscape is thus unknown.

Bactrocera (*T.*) *superba* appears to be most closely related to the Javanese *B.* (*T.*) *splendida* (Perkins), sharing with it the elongate antennal scape and pedicel (0.45 and 0.6 mm respectively), longer even than in *Semicallantra* – see Drew and Romig (2013) for comparative illustrations. It differs in the more extensive wing pattern and paler abdomen. The type locality (on label) is Goal (a village at 100 m altitude, 21 km N of Jailolo in NW Halmahera), not West Halmahera Gaol as indicated in Drew and Romig (2013).

B. (*Tetradacus*) undescribed species

(Figs 8-9)

Bactrocera (*Tetradacus*) sp. near *B. pagdeni*: White and Evenhuis 1999: 521.

Distribution. Eastern Indonesia (West Papua Province).

Male lure. None known.

Host plant. None known.

Comments. This species, known from a single male (Figs 8-9) in the Natural History Museum, London, resembles *B. pagdeni* but lacks the extensive wing infuscation, has extensive red-brown areas on the scutum and abdominal segments III-V, including the ceromata, are entirely red-brown. It is labelled 'New Guin' [circular label with '62 91' on reverse] / 'New Guinea. Coll. by A.R. Wallace. Bt. of Stevens. B.M. 1862-91'. Specimens so labelled were bought by the Museum from Wallace's London agent, Samuel Stevens and were collected in the Sorong area in Indonesia's West Papua Province (Baker 2001). The specimen [examined] has a slight emargination to sternite V and a short posterior surstylus lobe, wing cell c and most of cell bc extensively microtrichose and a patch of dense microtrichia at the end of vein A_1+CuA_2. The scutum is damaged by the pin and the medial yellow vitta represented by only a possible trace of it along the damaged edge posteriorly.

Species excluded from *Tetradacus*

Bactrocera fuscans (Wang, 1988) was synonymised with *B. brachycera* by Drew *et al*. (1998) but the recent availability of males of *B. brachycera* from India and Bhutan (Drew and Romig 2013) indicates that this was incorrect. The male of *B. brachycera* has a short posterior surstylus lobe (Drew and Romig 2013), while that of *B. fuscans* has an elongate posterior lobe typical of the *Zeugodacus* group of subgenera (Wang 1988). The female oviscape in *B. fuscans* is about twice as long as that of *B. brachycera*. *Bactrocera fuscans* also has a narrow postsutural medial yellow vitta and a largely black scutum, abdomen, face and legs. In the key of Drew and Romig (2016) it runs to subgenus *Asiadacus* Perkins, differing from other described species in the largely black face and abdomen (without a distinct dark medial vitta), broadly expanded apical spot on the wing and anepisternal stripe only as wide as the notopleural lobe. Originally described in genus *Sinodacus* Zia from Yunnan Province, southern China, we provisionally follow Wang (1998) in treating it in the combination *Bactrocera* (*Asiadacus*) *fuscans* (Wang).

The Papua New Guinean *B. fuscalata* Drew, 1989 was included in *Polistomimetes* (a synonym of *Tetradacus*) by Drew (1989) but it has a short posterior surstylus lobe and deep emargination to sternite V in males and is attracted to methyl eugenol. It was transferred to subgenus *Heterodaculus* Hardy (a synonym of *Apodacus*: this paper) by Norrbom *et al*. (1999) and this was followed by Clarke *et al*. (2004) and Doorenweerd *et al.* (2018); however, it has well developed ceromata on tergite V (slit-like in *Apodacus*) and, despite its lack of supra-alar and prescutellar acrostichal setae, is transferred here to subgenus *Bactrocera* Macquart.

Of the three additional species included in subgenus *Polistomimetes* by Drew (1989), the Australian *B. decurtans* (May, 1965) and *B. murrayi* (Perkins, 1939) were referred to subgenus *Bactrocera* by Norrbom *et al*. (1999) and Hancock (2015), while the East Indonesian (Papua Province) *B. toxopeusi* (Hering, 1953) (also included in *Heterodaculus* by Norrbom *et al*. 1999 and Doorenweerd *et al.* 2018) was referred to subgenus *Semicallantra* Drew by Hancock and Drew (2015).

Dacus discipennis Walker, 1861 from Bacan Island, eastern Indonesia, was included in subgenus *Tetradacus* by White and Wang (1992) and Norrbom *et al*. (1999). However, it has fused abdominal tergites and was placed in the combination *Dacus* (*Mellesis*) *discipennis* by Drew and Romig (2013).

Key to *Tetradacus* species

1 Wing with costal band broadly expanded apically, reaching vein M only in apical section beyond DM-Cu crossvein; scutum with presutural lateral yellow vitta from postpronotal lobe and postsutural medial yellow vitta both absent or vestigial; postpronotal lobe yellow; abdomen with black longitudinal and medial markings on at least tergites III-V [northern India and Bhutan] …… …….. *B.* (*T.*) *brachycera* (Bezzi)

– Not as above; wing with costal band reaching vein M throughout its length or not extending beyond mid-line of cell r_{4+5} and at most weakly expanded at apex; scutum with presutural lateral yellow vitta from postpronotal lobe and postsutural medial yellow vitta usually present, if both absent or vestigial then postpronotal lobe red-brown; abdomen with or without black longitudinal and medial markings ……..... 2

2 Scutum with presutural lateral yellow vitta from postpronotal lobe and postsutural medial yellow vitta both absent or vestigial; postpronotal lobe red-brown; wing with costal band reaching vein M throughout its length; prescutellar acrostichal setae weakly present [eastern Indonesia: Halmahera; Fig. 7] …… *B.* (*T.*) *superba* Drew & Romig

– Scutum with presutural lateral yellow vitta from postpronotal lobe present; postsutural medial yellow vitta usually present, if absent or vestigial then postpronotal lobe yellow; wing with costal band narrow, not reaching vein M; prescutellar acrostichal setae absent ……..... 3

3 Wing with costal band broadly crossing vein R_{4+5} into at least anterior halves of cells br and r_{4+5} and distinctly darker apically; abdomen distinctly petiolate, with segment I+II longer than broad [southern China, Nepal, Bhutan and NE India] ……..... *B.* (*T.*) *minax* (Enderlein)

– Wing with costal band at most narrowly crossing vein R_{4+5} into anterior part of cell r_{4+5} only and at most weakly darker apically; abdomen elongate-oval or ovate, with segment I+II broader than long 4

4 One or two pairs of supra-alar setae present; costal cells with microtrichia only in outer corner of cell c; abdomen with a dark medial vitta on tergites III-V [southern China and Japan (Kyushu, Amamioshima Is)] ..... ……... *B.* (*T.*) *tsuneonis* (Miyake)

– Supra-alar setae absent; costal cells with dense microtrichia over both cells bc and c; abdomen without a dark medial vitta on tergites III-V …. 5

5 Fore and mid femora fulvous with large black spots over apical two-thirds of outer surfaces; antennal scape and pedicel distinctly elongate [Indonesia: Java] ……..... *B.* (*T.*) *splendida* (Perkins)

– All femora fulvous; antennal scape and pedicel not distinctly elongate …… 6

6 Scutum fuscous; abdomen fuscous in females and with broad lateral fuscous margins in males; wing membrane extensively dark fulvous to dark fuscous [Solomon Is; Figs 4-6] …..... *B.* (*T.*) *pagdeni* (Malloch)

– Scutum with extensive red-brown areas; abdomen not as above; wing membrane at most with a pale fulvous tint …..... 7

7 Scutum red-brown without extensive fuscous markings; wing with costal band not crossing vein R_{4+5}; abdomen with broad lateral fuscous margins in females and anterolateral dark markings in males [Papua New Guinea; *B. neopagdeni* Drew is regarded as a synonym] ….....
..... *B.* (*T.*) *mesonotochra* Drew

– Scutum red-brown with distinct fuscous markings; wing with costal band narrowly crossing vein R_{4+5} into cell r_{4+5}; abdomen without distinct anterolateral dark markings in males [females unknown] [eastern Indonesia: West Papua Province; Figs 8-9] ..... Undescribed species

Discussion

Melanodacus group of subgenera

Subgenus *Neozeugodacus* was synonymised with *Hemizeugodacus* by Hardy (1955) but the presence or absence of the medial vitta, although not always reliable, appears to be a useful character in defining *Bactrocera* subgenera and no synapomorphy uniting them has been identified. Consequently, we here regard them as separate subgenera within the *Melanodacus* group.

The three known *Hemizeugodacus* species are allopatric and individually distinctive, occurring respectively in Borneo (*B. fulvosterna*), Philippines (*B. tetrachaeta*) and New Guinea-Australia (*B. aglaiae*). They are known only from biogeographical Zone B (South-East Asia: 2 species) and Zones D+E (New Guinea+Australia: 1 species), as detailed by Hancock and Drew (2015).

The four known *Neozeugodacus* species are also allopatric; *B. abdominingra* from Papua New Guinea, which has a black scutum and abdomen, appears to be the most distinctive, followed by *B. aurea* from Queensland, with its banded wing, lack of supra-alar setae and reduced basal scutellar setae. The two remaining species, *B. ektoalangiae* from NE Queensland and *B. buinensis* from Bougainville and the Solomon Islands, both lack basal scutellar setae and appear to form a species-pair. They are confined to Zone D (2 species) and Zone E (2 species).

The *Melanodacus* group is considered here to include seven subgenera: *Daculus* Speiser and *Gymnodacus* Munro from the Afrotropical Region, plus *Hemizeugodacus* Hardy, *Neozeugodacus* May, *Notodacus* Perkins, *Paratridacus* Shiraki (= *Hemisurstylus* Drew) and *Parazeugodacus* Shiraki (= *Melanodacus* Perkins) from the Indo-Australian Region. The number of included species and their biogeographical distributions are shown in Table 1. Previous Indo-Australian subgenera were reviewed by Hancock and Drew (2015, 2017a, b) and Afrotropical species were treated by White (2006).

Table 1. List of subgenera in the *Melanodacus* group, total number of species and number of species recorded from Africa (including Madagascar and Mascarenes) and the Indo-Australian biogeographic Zones A-F as detailed by Hancock and Drew (2015): A = Indian subcontinent; B = South-East Asia; C = Wallacea; D = New Guinea-Solomons; E = Australia; F = South Pacific. Species of *Hemizeugodacus* and *Paratridacus* in Zone E are shared with those in Zone D; all other species are endemic to their particular Zone.

Subgenus	**Total spp**	**Africa**	**Zone A**	**Zone B**	**Zone C**	**Zone D**	**Zone E**	**Zone F**
Daculus	**8**	8	0	0	0	0	0	0
Gymnodacus	**2**	2	0	0	0	0	0	0
Hemizeugodacus	**3**	0	0	2	0	1	1	0
Neozeugodacus	**4**	0	0	0	0	2	2	0
Notodacus	**4**	0	0	0	0	0	0	4
Paratridacus	**6**	0	1	3	0	2	1	0
Parazeugodacus	**8**	0	1	3	1	1	1	1
TOTAL SPECIES	**35**	**10**	**2**	**8**	**1**	**6**	**5**	**5**

The presence of a distinct lineage in the Afrotropical Region (*Daculus* and *Gymnodacus*), united by a dark anatergite, suggests that the *Melanodacus* group of subgenera originated in either India (Zone A) or South-East Asia (Zone B). The use of Oleaceae as primary host plants by both *Daculus* and *Parazeugodacus* suggests an ancestral relationship that is supported by molecular studies (San Jose *et al.* 2018), but the presence of a medial vitta in *Hemizeugodacus* suggests that it is the most primitive subgenus, the group thus originating in SE Asia. *Neozeugodacus* and *Notodacus*, restricted to the Australian Region (Zones D-F) are possibly also closely allied.

Bactrocera group of subgenera

Subgenus *Apodacus* is confined to the island of New Guinea and northeastern Australia (Zones D and E of Hancock and Drew 2015); the slit-like ceromata confirms the close relationship of the three included species and all occur in Central Province, Papua New Guinea. Subgenus *Semicallantra* is confined to the island of New Guinea and the neighbouring islands of southern Maluku (Zones C and D of Hancock and Drew 2015); available records suggest the species are largely allopatric, with a possible overlap in Morobe Province, Papua New Guinea, but further records are likely to show a higher degree of sympatry. The Ambonese *B*. (*S*.) *incompta*, with its largely pale abdomen and legs, is the most distinct. The four New Guinea species are largely fuscous to black, with *B*. (*S*.) *memnonia*, lacking postsutural lateral yellow vittae, being the most distinctive. The remaining species are characterised by the anteriorly tapered postsutural lateral yellow vittae (weakly so in *B*. (*S*.) *aquila*); in other *Bactrocera* taxa where these vittae taper, they do so posteriorly.

The relationship of *Apodacus* and *Semicallantra* to other subgenera within the *Bactrocera* group remains undetermined. *Apodacus* retains the postsutural medial yellow vitta, regarded as a plesiomorphic character seen in all three groups of subgenera and in *Tetradacus*, yet their slit-like ceromata are clearly an apomorphy. The subpetiolate abdomen seen in *Semicallantra* is shared with some species in subgenus *Tetradacus*, suggesting a similar plesiomorphic position, yet their different lure responses (methyl eugenol in *Apodacus* and cue lure in *Semicallantra*) and different antennal lengths suggest they are not closely related. Neither appears to be related to the *Bulladacus-Calodacus-Queenslandacus* subgroup, all of which have a shortened cell bcu and do not respond to any known male attractants. Nor can they be directly linked to the other lure-responding subgenera, *Bactrocera* s.s. and *Trypetidacus*. A molecular study by San Jose *et al.* (2018) placed *Apodacus* between *Tetradacus* and the *Melanodacus* group + all other *Bactrocera* group subgenera but did not include *Semicallantra*. Nevertheless, it supports both a primitive placement for *Apodacus* and its recognition as a distinct subgenus within the *Bactrocera* group.

The *Bactrocera* group of subgenera was considered to comprise eight subgenera by Hancock and Drew (2015) but one of these, *Notodacus* Perkins,

was transferred to the *Melanodacus* group of subgenera by Hancock and Drew (2017a). Seven subgenera in the *Bactrocera* group are thus recognised here: *Apodacus* Perkins, *Bactrocera* Macquart, *Bulladacus* Drew & Hancock, *Calodacus* Hancock, *Queenslandacus* Drew, *Semicallantra* Drew and *Trypetidacus* Drew, all endemic to the Indo-Australian Region and all likely originating in the Papuan Subregion. Subgenus *Bulladacus* was reviewed by Drew and Hancock (2016), while subgenus *Calodacus* was treated by Hancock (2015) and David *et al.* (2016). The number of included species and their biogeographical distributions are shown in Table 2.

Table 2. List of subgenera in the *Bactrocera* group, total number of species and number of species recorded from Africa (including Madagascar and Mascarenes) and the Indo-Australian biogeographic Zones A-F as detailed by Hancock and Drew (2015): A = Indian subcontinent; B = South-East Asia; C = Wallacea; D = New Guinea-Solomons; E = Australia; F = South Pacific.

Subgenus	Total spp	Africa	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
Apodacus	**3**	0	0	0	0	3	1	0
Bactrocera	**380+**	3*	43	96	74	135	60	26
Bulladacus	**20**	0	0	5	0	11	2	2
Calodacus	**8**	0	1	6	0	2	1	1
Queenslandacus	**1**	0	0	0	0	1	1	0
Semicallantra	**5**	0	0	0	1	4	0	0
Trypetidacus	**1**	0	0	0	0	1	0	0
TOTAL SPECIES	**418+**	**3***	**44**	**107**	**75**	**157**	**65**	**29**

*The African species (*B. invadens* Drew, Tsuruta & White, *B. latifrons* (Hendel) and *B. zonata* (Saunders)) are all adventives introduced from India.

Tetradacus

The shallow emargination to sternite V and short posterior surstylus lobe in males place *Tetradacus* in the *Melanodacus* group of subgenera but, although this association was weakly supported by Virgilio *et al*. (2015), other molecular studies (Krosch *et al*. 2012, Jiang *et al*. 2016, Song *et al.* 2018, San Jose *et al.* 2018) suggest that it is the sister-group to the *Melanodacus* plus *Bactrocera* groups of subgenera. *Tetradacus* also shows some morphological affinity with *Zeugodacus* group subgenera such as *Sinodacus* (especially in size, abdominal shape and wing pattern), although the TA stop codon to the COI gene (Jiang *et al*. 2016) excludes it from a direct relationship with the *Zeugodacus* group (which has the apparently plesiomorphic TAA stop codon) and associates it with the *Melanodacus* and *Bactrocera* groups. The large size and rutaceous host plants of at least some *Tetradacus* species (as in the more primitive dacine genus *Monacrostichus* Bezzi), plus the molecular studies

noted above, suggest a primitive position within genus *Bactrocera* and, until its precise relationships can be resolved, *Tetradacus* is best retained as a subgenus separate from both the *Melanodacus* and *Bactrocera* groups, as placed by Hancock and Drew (2015) and in recent molecular studies.

Available data suggest that the Indian-Bhutanese *B.* (*T.*) *brachycera*, with its short, non-cylindrical oviscape, is the most primitive species in the subgenus, indicating a centre of origin in the Indian subcontinent. Dispersal eastwards then presumably produced the species-pair *B.* (*T.*) *minax* and *B.* (*T.*) *tsuneonis* in East Asia and the Group B series (with a patch of dense microtrichia at the end of vein A_1+CuA_2 in males [secondarily acquired?]) in SE Asia, represented now by the species-pair *B.* (*T.*) *splendida* and *B.* (*T.) superba* in Java and Wallacea (with elongate antennal scape and pedicel) and the trio *B.* (*T.*) *mesonotochra*, *B.* (*T.*) *pagdeni* and the undescribed species in New Guinea and the Solomon Islands (with sexual dimorphism (where known) evident in abdominal shape and pattern). As noted by White and Wang (1992) and White (1999), the supra-alar and prescutellar acrostichal setae appear to have been lost or regained numerous times within genus *Bactrocera* (sometimes infraspecifically) and their presence/absence is not a reliable indicator of relationships. Both sets of setae occur weakly [secondarily?] in *B.* (*T.*) *superba*, supra-alars only in *B.* (*T.*) *tsuneonis* (1 or 2 pairs [again secondarily?]) and neither in the other species.

Table 3. Distribution of species in genus *Bactrocera* (including *Zeugodacus*) and subgenus *Tetradacus* in each biogeographic zone and percent endemism in *Tetradacus*. For a map of zones A-F see Hancock and Drew (2015).

Biogeographic Zone	**No. species *Bactrocera***	**No. species *Tetradacus***	**% *Tetradacus* endemic to Region**
(A) Indian subcontinent	74	2	50
(B) South-East Asia	225	3	67
(C) Wallacea	124	1	100
(D) New Guinea-Solomons	207	3	100
(E) Australia	75	0	-
(F) South Pacific	36	0	-

An Indian centre of origin is not unexpected, given the primitive nature of the subgenus, since genus *Dacus* Fabricius, the sister-taxon to genus *Bactrocera*, also appears to have originated there (Drew and Hancock 1999, Krosch *et al.* 2012). Table 3 shows the distribution and percent endemicity of the eight known species according to the biogeographic zones recognised by Hancock and Drew (2015). One species (*B. minax*) is shared between Zones A and B, the others are all endemic to a single Zone.

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COVER

The dragonfly, *Hemicordulia australiae* (Rambur), in the wheel position near a garden pond at Currimundi, on the Queensland Sunshine Coast. This species is widespread in Australia, the Lesser Sundas and New Zealand. At the stage depicted the male (top) has previously transferred his sperm from the testes at the tip of the abdomen to the seminal vesicle on the second segment near the base of the abdomen. The female has made genital contact forming the heart-shaped 'wheel', during which the male inseminates her. Pen and ink drawing by *Australian Entomologist* subscriber, Dr Albert Orr, whose illustrated books on dragonflies and butterflies have won awards in Australia and overseas.

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